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LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY

VOLUME II ✦ REQUIREMENTS, DESIGN, AND PLANNING STUDIES FOR THE CARRY-ON LABORATORIES

GENERAL DYNAMICS
Convair Division

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VOLUME II ✦ REQUIREMENTS, DESIGN, AND PLANNING STUDIES FOR THE CARRY-ON LABORATORIES

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FOREWORD

The work performed under this contract, NAS8-30288, was divided into three separate elements as specified in the contract work statement. These were (Element 1) Carry-On Laboratory Definition and Integration Studies, (Element 2) Cost Analysis of the Dedicated 30-Day Laboratory, and (Element 3) Update of Dedicated 30-Day Laboratory Data Management Requirements. This volume (II) contains a description of the work carried out under Element 1 of the contract. . Elements 2 & 3 are reported in the Appendix (Volume IV) of this final report.

This report consists of the following volumes:

Volume I	Executive Summary
Volume II	Requirements, Design, and Planning Studies for the Carry-On Laboratories
Volume III	Preliminary Equipment Item Specification Catalog for the Carry-On Laboratories
Volume IV	Appendix, Costs and Data Management Requirements of the Dedicated 30-Day Laboratory

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MAJOR ACRONYMS AND SYMBOLS

ARC	Ames Research Center
BEST	Bioexperiment Support & Transfer
CER	Cost Estimating Relationship
CDMS	Command and Data Management Subsystem
COL	Carry-On Laboratory
CRT	Cathode Ray Tube
CVT	Concept Verification Test
EC/LSS	Environmental Control/Life Support Subsystem
ECG	Electrocardiogram
ECS	Environmental Control System
EEG	Electroencephalogram
E.I.	Equipment Item
EMG	Electromyogram
ESE	Experiment Specific Equipment
FL	Flight
FPE	Functional Program Element
G&A	General & Administration
GFE	Government Furnished Equipment
GPRE	General Purpose Research Equipment
GSE	Ground Support Equipment
HQTRS	Headquarters (NASA)
IMBLMS	Integrated Medical & Behavioral Laboratory Measurement System
JSC	Johnson Space Center
K	One Thousand (e.g., $K or Kbits)
LBNP	Lower Body Negative Pressure
LSPS	Life Support & Protective Systems
M	One Million
MSFC	Marshall Space Flight Center
NR	Non-recurring
R	Recurring (cost)
RAM	Research Applications Module
R-O	Recurring Operations (cost)
R-P	Recurring Production (cost)
SEB	Source Evaluation Board
SRT	Supporting Research & Technology
SSPDA	Space Shuttle Payload Development Activity
VCG	Vectorcardiogram
WBS	Work Breakdown Structure

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SECTION 1

INTRODUCTION

This study was performed under Contract NAS8-30288 as an integral part of current NASA planning activity to define potential research laboratories to be flown in future spacecraft such as the Space Shuttle. This study is one of a series defining potential life sciences laboratories for future spacecraft. It and the preceding studies have been conducted under the guidance of the Life Sciences Payload Integration Team, which includes representatives from NASA Headquarters, MSFC, ARC, and JSC.

1.1 BACKGROUND

The life sciences research discipline includes the seven functional program elements (FPEs) of biomedicine, vertebrates, cells/tissues, plants, invertebrates, man/systems integration (MSI), and life support and protective systems (LSPS). This study deals with life sciences Carry-On Laboratories (COLs), which are small, primarily self-contained modules capable of supporting the life sciences research on early flights of opportunity of the Space Shuttle. They could be placed aboard a multi-purpose Spacelab or in some cases the crew compartment of the Shuttle Orbiter. The study of these COLs was preceded by two related studies dealing with larger life sciences laboratories, which led into the current study. All three studies are outlined below and their interrelationship is shown in Figure 1-1. In Figure 1-1, RAM (Research Applications Module) and Sortie Module refer to spacecraft vehicles which preceded the current Spacelab but were similar in concept.

a. October 1970 to March 1972 — Life Sciences Payload Definition and Integration Study (Tasks A & B), Contract NAS8-26468, Reference 2. This contract established comprehensive inventories of scientific functions and related equipment necessary to perform life sciences research in space. NASA personnel, NASA documents, and consulting scientists were utilized in making up these inventories. Mission parameters and other constraints were purposely not imposed so that comprehensive baseline inventories could be obtained. These inventories were then utilized in the definition of conceptual life sciences spacecraft laboratory designs. A general philosophy of a laboratory "facility" was used throughout the study in order to provide the flexibility to accommodate future unknown experiments. Four baseline conceptual designs created by this effort were characterized as:

   (1) Maximum Laboratory (Maxi-Max). A reference baseline providing full life sciences research capability.

   (2) Maximum Nominal Laboratory (Maxi-Nom). Foreseen as the most comprehensive laboratory that could be flown with a space station complex.

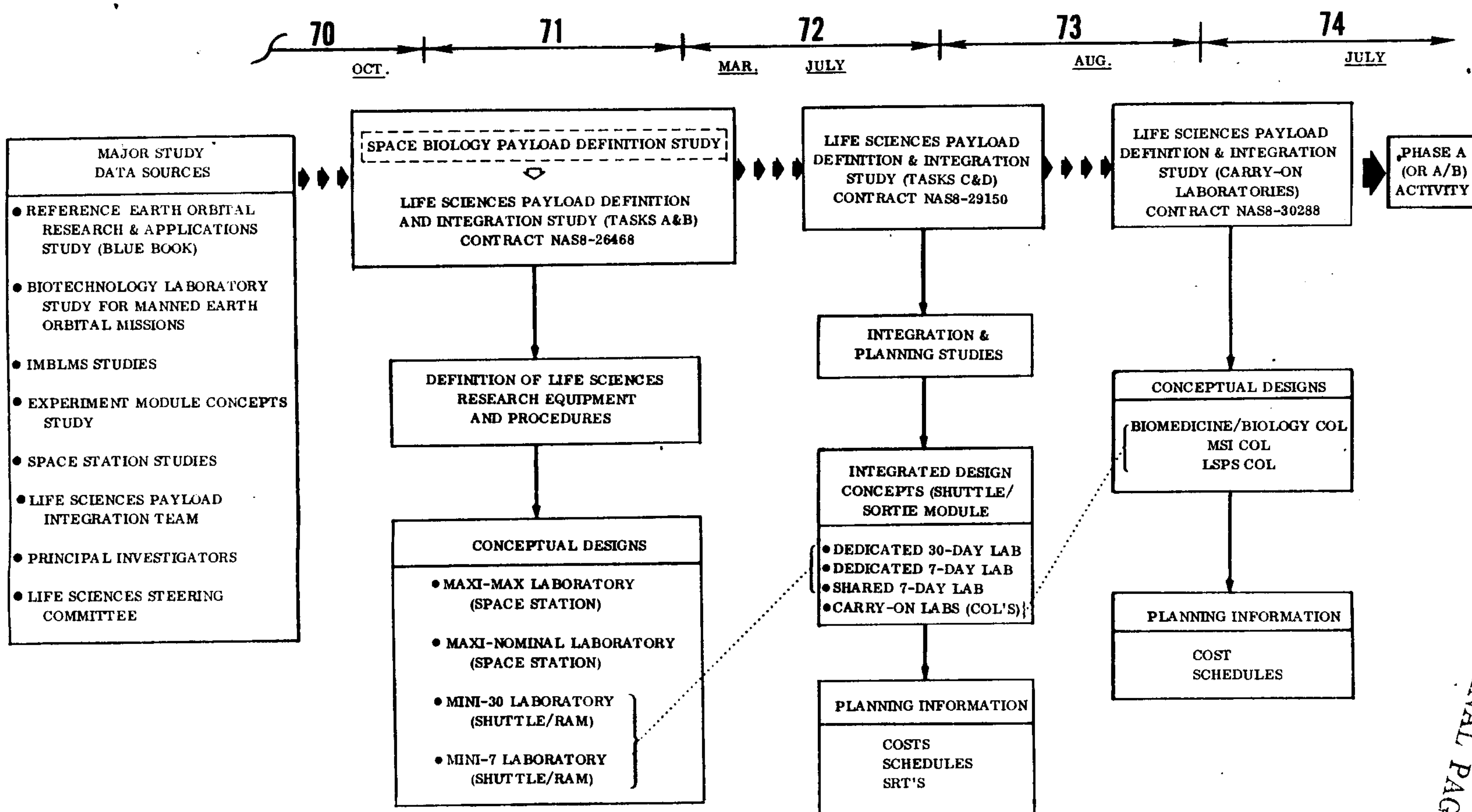


Figure 1-1. History of Life Science Payload Definition and Integration Studies

(3) Minimum-30 Laboratory (Mini-30). Applicable to an initial space station mission as well as a 30-day Shuttle/RAM (Spacelab) flight.

(4) Minimum-7 Laboratory (Mini-7). To operate in a Shuttle/RAM (Spacelab) mode of 7 days' mission duration.

These payloads encompass a range of capabilities from full capability to respond to all research goals down to lesser capability payloads with defined reductions in facility weight, volume, power, and cost for defined reductions in scientific responsiveness.

b. <u>July 1972 to August 1973 — Life Sciences Payload Definition and Integration Study (Tasks C & D), Contract NAS8-29150, Reference 1.</u> This study concentrated on the two smallest laboratories from the previous program and investigated their compatibility with the Shuttle/Sortie Module (similar to Spacelab) mission. Initial work involved updating these laboratories and related equipment items as directed by the NASA Life Sciences Payload Integration Team. The second major task was the determination of subsystems aboard the Sortie Module (Spacelab) which would be required to support the life sciences laboratories. This included studies of the organism environmental control subsystem, data management subsystem, electrical power subsystem, thermal control subsystem, and crew environmental control and life support subsystem. Additional activity included determination of cost profiles, development schedules, and significant supporting research and technology associated with the life sciences laboratory development. The study also generated preliminary conceptual designs of several carry-on laboratories. The major life sciences laboratory concept resulting from this study was designated the 30-Day Dedicated Laboratory, and would completely fill the Spacelab.

c. <u>August 1973 to July 1974 — Life Sciences Payload Definition and Integration Study (Carry-On Laboratories), Contract NAS8-30288.</u> This contract is the subject of this volume and was primarily directed toward the definition of various carry-on laboratories. Research guidelines were provided by the NASA Life Sciences Steering Committee and the spacecraft interface guidelines were updated to reflect new information obtained from the European Space Research Organization Spacelab program. Design concepts were defined for several categories of carry-on laboratory payloads ranging from 23 to 275 kg (50 to 600 lb). The data defining these carry-on laboratory designs, development schedules, and costs were taken to the same level of detail as for the larger Shared and Dedicated Laboratories. More detailed information on the Carry-On Laboratory (COL) study is contained below.

1.2 MAJOR TASKS AND ORGANIZATION OF THE STUDY

The COL study was divided into four major tasks:

Task A. Identification of research requirements of the COLs. This included definition of research areas and functions to be supported as well as the potential equipment needed to support the desired research. (See Section 2.)

Task B. Development of a number of conceptual layouts for the COLs based on the research and equipment defined during Task A. These potential COL designs were reviewed by NASA and several favored concepts were selected for the final design and integration studies to follow in Task C. Task B is described in Section 3.

Task C. Analysis of COL integration parameters and development of final conceptual designs for the selected COLs. (See Sections 4 and 5.)

Task D. Development of COL planning information, including design drawings of a selected COL to permit fabrication of a functional breadboard of that COL. (See Section 4.2.5.) Other planning information included definition of COL/Spacelab interface data, cost data, and program cost schedules. (See Section 6.)

These tasks are all dependent on an accurate definition of general purpose research equipment needed in the COLs. Obviously, the conceptual and breadboard designs rely heavily on the equipment to be incorporated in these designs, and the generation of cost data is a direct function of the specific equipment to be designed, developed, or purchased. Also, the study of integration and interface characteristics of the COLs will depend on the equipment incorporated therein. For these reasons, equipment specification data was compiled early in the study and updated throughout. The specifications for all equipment items contained in the final COLs are contained in Volume III of this report. Because of the conceptual design status of the COLs, these specifications are still very preliminary in nature but comprise a significant output of the study. Volume III is a working document comprised of information to be updated as future COL definition progresses.

A facility approach to design was used throughout this study. That is, general categories of research rather than specific experiments were used as COL design criteria. This approach led to general purpose equipment that could be used by a large cross-section of experiments. Thus, some general-purpose equipment in the COLs may be deleted for specific experiments and other experiment-specific equipment added.

1.3 GUIDELINES FOR CARRY-ON LABORATORY DEFINITION

At the beginning of this study, an initial set of guidelines was presented to the contractor by NASA, and at the beginning of Task C several new guidelines were presented.

The initial guidelines are presented below, and the subsequent guidelines are presented in Section 4.1.

a. COLs will be compatible with the European Space Research Organization (ESRO) Spacelab (carried in the Shuttle Orbiter).

b. COL preliminary conceptual designs will be consistent with the following preliminary constraints.

   1. Manpower availability: ~ 2 hr/day (baseline), up to 1 man full time (considered).

   2. Weight: 136 to 170 kg (300 to 375 lb). (Later modified as described in Section 4.1.1.)

   3. Number of modules: 2 (baseline) plus additional module(s) for 30-day capability.

   4. Modules will be capable of fitting through a 102-cm (40-inch) hatch.

   5. No electrical power limits were specified. Power requirements were to be defined.

c. Analyses required during the research will be performed subsequently on the ground if the desired results could be obtained by so doing. Thus, the emphasis is on preparation and preservation of specimens in space.

d. Low-cost, off-the-shelf equipment will be used where possible.

e. A separate, isolated environmental control system (ECS) will be used for the organisms. This guideline was changed early in the study to the specification of an open system, ventilating the organisms with cabin air. The purpose was to expose the organisms to the same atmosphere as that of the crew.

f. The baseline COL will be designed for 7 days, and additional requirements (deltas) for a 30-day capability will be defined. The first flight is assumed scheduled for 1980.

In addition to these guidelines, NASA provided direction as to the research areas to be emphasized in the design of the COLs. These research areas were specified for the two FPEs of MSI and LSPS and the rest of the FPEs under the heading of biomedicine/biology. Thus, these three major FPE or FPE groups were used throughout the study. The research and equipment guidelines and requirements for each are described in Section 2.

SECTION 2

DEFINITION OF RESEARCH AREAS AND CANDIDATE RESEARCH EQUIPMENT FOR THE CARRY-ON LABORATORIES (TASK A)

Before conceptual design activity could commence on the life sciences Carry-On Laboratories (COLs), the areas (or types) of research to be supported needed to be established. This, in turn, allowed candidate research equipment to be selected for inclusion in the Carry-On Laboratories and was the major work performed during Task A.

The definition of research areas and equipment was based on the equipment and functional inventories developed during the previous Life Sciences Payload Definition and Integration Study, NAS8-26468, Reference 2. NASA personnel reviewed these inventories and specified either specific research functions or research areas to be supported by the COLs in the various FPE areas. These NASA guidelines were received at the beginning of the current contract and used as the starting point in establishing equipment inventories for the COLs.. The procedures used and the resulting equipment lists for the COLs are discussed in this section. The research areas and equipment lists presented are slightly different from those used during the final phases of the subject contract. The equipment lists presented in this section were used to generate the conceptual COL layouts presented in Section 3. Due to the evolutionary nature of the designs, these lists went through several iterations and were updated as the conceptual design drawings and breadboard design drawings were generated toward the end of the study. The final lists of equipment are presented in Section 4. Detailed equipment definition sheets were prepared on each of the final equipment items and are included in Volume III.

2.1 BIOMEDICINE AND BIOLOGY

2.1.1 RESEARCH AREAS. For biomedicine and biology, the general areas of desirable research for the COLs were determined by the study team. This task was initiated by studying NASA guideline documents to obtain a list of research areas in order of priority for the Carry-On Laboratories. The research areas were used to determine measurements, procedures, and equipment necessary for their support. Certain items of equipment, such as animal and plant housing units, cages, and biological monitoring instrumentation, are definitely required onboard. Much equipment, however, is used for measurements and analysis of specimens such as blood, tissue, etc. The related equipment can be carried on board to analyze these specimens in real time, or the specimens can be collected and stored for return to earth and analysis in ground-based laboratories. The weight and size limitation of the COLs generally led to the decision to perform biochemical, cytological, and histological analytical procedures on the ground. Thus, equipment items required for preparation, preservation, and storage of biological specimens were included in the COLs. In some cases, biological samples could not be stored for the required seven or more days before accomplishing ground analysis, so onboard devices for real-time analysis were provided.

Table 2-1 lists the guideline documents applicable to the definition of the biomedicine and biology Carry-On Laboratories. The first four documents provided the NASA research objectives and equipment selection guidelines. Documents 5 and 6 presented data defining preparation and preservation techniques and equipment items used in the Skylab missions that had high potential for application in Carry-On Laboratories. Document 7 described techniques for specimen preparation and preservation, along with information defining required fixative shelf lifes of the stored specimen and estimates of technician time for these activities. This reference was used heavily in the determination of onboard versus ground analysis of biological samples. The 8th document, which was a reference document used in an earlier phase of this contract, provided a comprehensive listing of functions necessary for performing plant and invertebrate research. Information from this document was used to augment the information provided by the NASA guidelines for plant and invertebrate COLs. Documents 9, 10, and 11 provided existing descriptions of space research functions and equipment to serve as candidates for use in the COLs.

The research areas defined by the guideline documents for the Biomedical COL were listed as interpreted by the project team in order of descending priority as shown in Table 2-2. The priorities, as defined by the comprehensive guideline document provided by the Life Science Payload Integration team, were used as a basis against which the priorities on the other three source documents were compared. Excellent agreement

Table 2-1. Guideline Documents for Biomedicine and Biology COLs

1. MEMO TO NASA CENTERS LIFE SCIENCES PAYLOAD INTEGRATION STUDY STEERING COMMITTEE FROM ROBERT W. DUNNING, SUBJ: DISCIPLINE PRIORITY GUIDANCE FOR CURRENT LIFE SCIENCES PAYLOAD INTEGRATION STUDY (MSFC/NAS8-29150), JULY 25, 1972.

2. "PLANNING GUIDANCE FOR IDENTIFICATION AND LAYOUT OF LIFE SCIENCES 'CARRY-ON' PAYLOADS FOR SHUTTLE SORTIE MISSIONS," AUGUST 9, 1972.

3. MEMO TO ROBERT W. DUNNING FROM S. P. VINOGRAD, M.D., SUBJ: CANDIDATE RESEARCH FUNCTIONS FOR "CARRY-ON MINI-LAB", JULY 25, 1973.

4. MEMO TO ROBERT W. DUNNING FROM S. TOM TAKETA, SUBJ: CANDIDATE RESEARCH FUNCTIONS FOR SHUTTLE CARRY-ON MINI LAB CONFIGURATION," AUGUST 23, 1973.

5. "SKYLAB AND THE LIFE SCIENCES," NASA-MANNED SPACECRAFT CENTER, FEBRUARY 1973.

6. "BIOMEDICAL EXPERIMENTS AND SYSTEMS IN SKYLAB," NASA-MANNED SPACECRAFT CENTER, APRIL 1971.

7. "SURVEY OF TECHNIQUES USED TO PRESERVE BIOLOGICAL MATERIALS," E. J. FEINLER & R. W. HUBBARD, STANFORD RESEARCH INSTITUTE (CONTRACT NAS2-6201), JANUARY 1972.

8. FINAL REPORT, "REQUIREMENTS STUDY FOR A BIOTECHNOLOGY LABORATORY FOR MANNED EARTH-ORBITING MISSIONS - PHASE II, VOLUME I: DESCRIPTION OF REQUIREMENTS," MC DONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST, REPORT MDC G0620 (CONTRACT NAS1-9248), JULY 1970.

9. IMBLMS PHASE B-4 REPORTS, BOTH GENERAL ELECTRIC & LOCKHEED MISSILES & SPACE CO.

10. TASK A&B, FINAL REPORTS, GENERAL DYNAMICS CONVAIR AEROSPACE DIV., NAS8-26468, MARCH 1972.

11. TASK C&D, FINAL REPORTS, GENERAL DYNAMICS CONVAIR AEROSPACE DIV., NAS8-29150, AUG. 1973.

Table 2-2. Research Area Priorities for Biomedical and Biomedical Surrogate COL Missions

RESEARCH AREAS	PAYLOAD INTEGRATION TEAM-AUG. 72	STEERING COMMITTEE-JULY 72	HDQTS., JULY 1973	ARC, SEPT. 1973	SKYLAB	*VERTEBRATE	*CELLS & TISSUES
CARDIAC FUNCTION	1	1	2	1	TO BE DETERMINED	CARDIAC FUNCTION	BIOCHEMICAL PROPERTIES
PULMONARY FUNCTION	2	2	3	2		PULMONARY FUNCTION	BIOPHYSICAL PROPERTIES
HEMODYNAMICS	3	3	4	3		HEMODYNAMICS	RADIATION EFFECTS
BLOOD MORPHOLOGY						BLOOD MORPHOLOGY	MORPHOLOGY
ELECTROLYTES						ELECTROLYTES	
ENZYMES						ENZYMES	
ENDOCRINES						ENDOCRINES	
GASES						GASES	
ORGANISMS						ORGANISMS	
IMMUNOGLOBINS						IMMUNOGLOBINS	
PROTEINS						PROTEINS	
CHEMISTRIES						CHEMISTRIES	
G.I. FUNCTIONS	4	6	-	5		G.I. FUNCTIONS	
EXCRETORY FUNCTIONS	5	7	4	4		EXCRETORY FUNCTIONS	
METABOLIC STUDIES	6	5	4	6		METABOLIC STUDIES	
MICROBIOLOGY STUDIES	6	-	5	6		MICROBIOLOGY STUDIES	
NEUROLOGICAL FUNCTIONS	7	8	1	7		NEUROLOGICAL FUNCTIONS	
VESTIBULAR FUNCTIONS	7	4	6	6		VESTIBULAR FUNCTIONS	

HI

PRIORITY

LO

*PARALLEL BIOMEDICAL RESEARCH OBJECTIVES TO STUDY BASIC MECHANISMS OF MAN'S ADAPTATION TO THE SPACE ENVIRONMENT.

with regard to giving high priority to cardiac function, pulmonary function, and hemodynamic studies was shown for all source documents. The order of priority, as established by the Life Science Payload Integration team guideline, represented the aggregate NASA guideline priorities except that neurological function and vestibular function research was given high priority by two of the sources.

Application of the vestibular and neurological research to an understanding of the transient functional disturbances in the first Skylab crew provided a rationale for giving the vestibular and neurological functions a high priority. However, from the viewpoint of crew safety, assessment of vestibular or labyrinthine disturbances in the reduced gravity of space will, from the clinical standpoint, be heavily dependent on signs and symptoms (disorientation, vertigo, reflex nausea, vasomotor response, nystagmus, etc.). Dealing with these factors is more the function of a qualified onboard medical observer than of COL design. From the standpoint of performing basic research on vestibular functions in space, there is a requirement for equipment such as a rotating litter chair. The weight and volume for such a device precludes its inclusion in a COL. However, in agreement with NASA guidelines, interfaces will be provided in the COL to support vestibular research with a rotating litter chair if this device were taken aboard a spacecraft as an experiment specific item.

Similarly, the high priority for neurological functions would be served by the COL concept. For example, a vision tester is included as an equipment item on one of the candidate man/systems integration COL concepts. Cellular and tissue preparations for cytological and histological studies on nervous tissue would be provided by man-surrogate research, which could be conducted with the vertebrate and cell and tissue COLs. The presence of an onboard medical observer for a neurological examination and history would provide coverage from the clinical and crew safety standpoint.

The discrepancy in priorities of vestibular and neurological studies are accommodated by the total COL concept, which does provide the capability to deal with research requirements in these areas. As a result of the Skylab biomedical research program, the priorities for biomedical research in space were changed. A blank column entitled Skylab is shown in Table 2-2 to highlight the fact that Skylab priorities, when they became available, were to be used. (See Section 4.)

As indicated in Table 2-2, biomedical, vertebrate, and cell and tissue human-emphasis research objectives provided by NASA guidelines were grouped under the general title, Research Area Priorities for Biomedical and Biomedical-Surrogate COLs. This grouping was chosen to emphasize the dual role played by vertebrate and cell and tissue space research. One role would be achieved by research at the subcellular and cellular level on animals, with cells and tissues serving as man-surrogates to accomplish studies related to man that could not be performed directly on human subjects. For example, excision of myocardial tissue on vertebrates might disclose weightless-induced degenerative or atrophic changes not measurable through electrophysiological monitoring on man.

Bone marrow, glandular, gastrointestinal tract, and renal tissue biopsies could support cytological and histological studies, providing insight regarding basic mechanisms of zero-g adaptation, metabolism, radiation effects, genetic changes, etc.

The second very important role served by the vertebrate and cell and tissue research capabilities would enable comprehensive basic science investigations directed toward a better understanding of the vertebrate and cell and tissue disciplines within their own right. These research areas are shown with the plant and invertebrate COL research areas under the title, Basic Science Research Objective, Table 2-3.

Table 2-3. Basic Science Research Areas for Vertebrate, Cell and Tissue, Plant and Invertebrate COL Missions

VERTEBRATES	CELLS & TISSUES	PLANTS	INVERTEBRATES
GROWTH	GROWTH	GROWTH	GROWTH
DEVELOPMENT	DEVELOPMENT	DEVELOPMENT	DEVELOPMENT
REPRODUCTION	METABOLIC STUDIES	METABOLIC STUDIES	METABOLIC STUDIES
EMBRYOGENESIS	HOST-PARASITE RELATIONS	BIOCHEMICAL PROPERTIES	BIOCHEMICAL PROPERTIES
SENESCENCE & AGING	GENETICS	MORPHOLOGY	MORPHOLOGY
GENETICS	RADIATION/HZE PARTICLE EFFECTS	EMBRYOGENESIS	EMBRYOGENESIS
RADIATION/HZE PARTICLE EFFECTS		HOST-PARASITE RELATIONS	RADIATION/HZE PARTICLE EFFECTS
		GENETICS	
		RADIATION/HZE PARTICLE EFFECTS	

2.1.2 CANDIDATE EQUIPMENT FOR BIOMEDICINE AND BIOLOGY COLs. Equipment selection guidelines extracted from the NASA documents are:

a. Maximize use of off-the-shelf equipment.

b. Maximize use of common-purpose equipment.

c. Minimize onboard analysis.

d. Emphasize modular design and interchangeability.

e. Assume ionizing radiation shielding and containment equipment will be experiment-specific.

f. Assume data management (memory, calculation, transmission) is provided by spacecraft systems.

g. Provide interfaces in COL to support experiment-specific functions (i.e., lower body negative pressure, rotating litter chair, primate holding unit).

Guidelines a, b, c, d, and f emphasize cost effectiveness. Guideline e, dealing with ionizing radiation, shielding, and containment equipment as experiment-specific, is intended to prevent compromising design of all COLs to accommodate an occasional radiation experiment. Guideline g would enable the COL to provide support for special studies using large equipment items that exceed COL wiehgt, power, and volume constraints. If such items (i.e., primate housing unit) were used for space research missions in conjunction with the COL, the COL facilities for data recording, display and storage, and for specimen preparation, preservation, and storage can be used to support such correlated research. Another selection guideline, as discussed previously, was that the vertebrates and cells and tissues would serve as biomedical surrogates to study mechanisms of man's adaptation to the space environment as well as to support basic science studies.

The research areas discussed previously were used in defining research functions and related equipment needed in the COLs. The functions and equipment inventories developed in the previous life sciences payload definition and integration contracts were used as the principal data source. Additional research functions were obtained from the reference documents to augment NASA guidelines and ensure a more comprehensive functions definition to serve as a basis for selecting COL equipment items. An example of some typical research functions that must be performed in the pursuit of plant research is shown in Table 2-4.

Table 2-4. Representative Plant Research Functions List for COL

GROWTH & DEVELOPMENT

GROWTH RATE
SEEDING CELL ORGANIZATION
ROOT DEVELOPMENT
FLOWER SYMMETRY
LEAF SYMMETRY
POLLEN MATURATION
GERMINATION TIME
GEOTROPISM/PHOTOTROPISM
SEED MORPHOGENESIS
CYTOLOGIC STAINING
STOMAL OPENING

PHYSIOLOGY

CHLOROPLAST METABOLISM
PHOTOSYNTHETIC ACTIVITY
VIRAL IDENTIFICATION
FUNGAL IDENTIFICATION

COMMON OPERATIONS

SPECIMEN STATUS OBSERVATION
AIR SAMPLING
MICROSCOPY
MASS MEASUREMENTS
BIOSAMPLING
OXYGEN MONITORING
CO_2 MONITORING
WATER VAPOR MONITORING
RADIATION MONITORING

BIOCHEMISTRY

TOTAL NITROGEN
CARBOHYDRATE CONTENT
WATER-MINERAL TRANSPORT
PLANT HORMONE ASSAY
  PHYCOCYANIN
  PROTOPORPHYRINE
PLANT ENZYME ASSAY
  INVERTASE ACTIVITY
  GEHYDROGENASE ACT.
  PEROXIDASE.
PLANT LIPIDS
AMINO ACID ASSAY
ISOTOPIC UPTAKE (C, Ca, N, P)
STARCH GRANULE ASSAY
ALKALOID SYNTHESIS
CARBON DIOXIDE EVOLUTION
OXYGEN UPDATE

The research functions determined for all FPEs were studied to determine if specimens must be collected to meet the function requirement and, if so, what type of specimen was involved. The manner in which the specimens must be preserved and the equipment requirements for preparing the specimens for storage were likewise evaluated. In addition, the clinical significance attached to the various specimens and the crew time for preparation and preservation were estimated. This data enabled determination of whether a given research function would be performed on board the space vehicle or subsequently on the ground. In either instance, equipment items required for the sample collection, preparation and preservation, and/or onboard analysis were defined to satisfy each research function.

An initial list of equipment items (EIs) for all biomedical and biological FPEs is shown in Table 2-5. This list was used as a starting point in defining the equipment to be included in biomedical and various biological COLs. Since it was large and contained many small items, it was condensed and modified to be more usuable in the COL layout and design activities to follow. The resulting list is shown in Table 2-6. The reduction in the number of EIs in this list resulted primarily from grouping many of the smaller items into kits. Some reduction was also achieved through a screening procedure that resulted in elimination of EIs of secondary importance.

An additional category of research was added to Table 2-6 based on direction from NASA to include the study of small vertebrates as man surrogates. This guideline gives rise to the concept of two vertebrate COLs employing slightly different equipment.

The list of EIs in Table 2-6 was approximately that which was used in the preliminary layout activity phase of the study, Section 3. However, this list was continually improved and updated throughout the study as appropriate NASA or vendor contacts were made. The final equipment list is shown in Section 4 of this volume and in Volume III.

2.2 MAN/SYSTEMS INTEGRATION RESEARCH AREAS AND EQUIPMENT SELECTION

The research areas and equipment requirements for several candidate man/systems integration (MSI) laboratories are discussed in this section. The requirements are based on the research areas and experiments identified by the NASA in a memorandum to R. Dunning, MMC, form S. Deutsch, MME/Director, Bioengineering Division, "Identification of Candidate Bioengineering Experiments Function Requirements," dated June 14, 1973.

2.2.1 CANDIDATE EQUIPMENT SELECTION. The June 14 memorandum listed NASA's 19 MSI experiment interest areas for the COLs and the research functions required by each. The functions specified were taken from the functions inventory developed during the previous life sciences payload definition and integration contracts. Equipment required to perform each function was identified from this inventory and cross-tabulated with the appropriate experiments in Table 2-7. The 19 experiments of interest are listed across the top of the table. Convair recommended that the first two experiments

Table 2-5. Initial List of Equipment Items for Biomedical and Biological FPEs

EQUIPMENT ITEMS	USING F.P.E.'S BIO-MEDICINE	SMALL VERTE-BRATES	CELLS & TISSUES	PLANTS	INVERTE-BRATES
SPECIMEN ACQUISITION					
AIR PARTICLE SAMPLER	X	X	X	X	X
ALCOHOL SWABS	X	X	X	X	X
ANESTHETIZER, INVERTEBRATE					X
BIOBACKPACK, MICRO		X			
BLADES, SURGICAL (25 PK)	X	X	X	X	X
CHLORAL HYDRATE		X			
CUFF, BLOOD PRESSURE	X				
ELECTRODES, EEG, EXG, DISPOSABLE	X	X			
FLOWMETER, DOPPLER, BLOOD	X	X			
FORCEPS, GILBERT		X	X	X	X
FORCEP, NEEDLE, METZENBAUM		X	X		X
FORCEPS, SPLINTER	X	X	X	X	X
FORCEPS, TISSUE (RATTOOTH), MICHEL		X	X	X	X
HARNESS, ELECTROPHYSIOLOGY	X				
HARNESS, ELECTROPHYSIOLOGY, MICRO		X			
KNIFE HOLDER, BARD PARKER		X	X	X	X
LANCETS (25/KIT)	X	X			
LOOP, INOCULATING	X	X	X	X	X
MEDIA, BLOOD AGAR, PLATED	X	X	X		X
MEDIA, EMB AGAR, PLATED	X	X	X		X
MEDIA, FLUID, EXP. SPECIFIC	X	X	X	X	X
MEDIA, PHENYLETHYL ALCOHOL AGAR	X	X	X		X
MEDIA, SOLID, EXP. SPECIFIC			X	X	
MEDIA, TSA AGAR, PLATED	X	X	X		X
MICROSURGERY SET		X	X	X	X
NEEDLE, INOCULATING	X	X	X	X	X
NEEDLES, VACUTAINER, 21 GA., 26 GA.	X	X			
NEMBUTAL		X			
ORGANISM TRANSFER/RESTRAINT CAPSULE		X			
PIPETTES, OXFORD SAMPLER	X	X	X	X	X
RESPIROMETER, STRAIN GAGE	X	X			
RETRACTOR, WEITLANER		X			X
SCISSORS, BABY OPERATING		X	X	X	X
SCISSORS, MAYO-NOBEL, DISSECTION		X	X	X	X
SCISSORS, OPERATING		X		X	
SPIROMETER MOUTHPIECES	X				
SYRINGES, 1 CC (20/KIT)	X	X	X	X	X
SYRINGE, BLOOD COLLECTING (EA)	X	X			
SYRINGE, VACUTAINER, PED SIZE (25/KIT)	X	X			
THERMISTOR, DEEP BODY TEMP.	X	X			X
XDCR, VENOUS PRESSURE, IMPLANTABLE		X			
ZERO G RESTRAINING DEVICE, EQUIPMENT	X	X	X	X	X
SPECIMEN PREPARATION					
ANIMAL DISSECTION BOARD, UNIVERSAL		X			
CENTRIFUGE, MICROCHEMICAL/HCT	X	X	X		X
COUNTER, DIFFERENTIAL		X	X		X
COUNTER, TALLY	X	X	X	X	X
COUPLER, DOPPLER FLWMTR.	X	X			
COUPLER, EEG	X	X			
COUPLER, EMG	X	X			
COUPLER, PRESSURE XDCR	X	X			X
COUPLER, STRAIN GAGE	X	X			X
COUPLER, THERMISTOR	X	X			X
COUPLER, VECTORCARDIOGRAM	X	X			
COVER SLIP (COUNTING CMBR)	X	X	X	X	X
CRITOSEAL	X	X	X		X
DISSECTION BOARD CLIPS (PACKAGE)		X			
GAUZE, 2×2, SPONGES (200)	X	X	X		X
GLOVE BOX		X	X	X	X
HOMOGENIZER, .2 TO 50 ML		X	X	X	X
LYOPHILIZER, SPACE VACUUM (MANIFOLD)		X	X	X	X
MICROSCOPE, DISSECTING		X	X	X	X
NEEDLES, ASSORTED SIZES	X	X	X	X	X
NEEDLES, SUTURE, ASSORTED SIZES		X			
ORGANISM/SPECIMEN MASS MEAS. DEVICE		X		X	X
PIPETTES, OXFORD SAMPLER	X	X	X	X	X
RADIOBIOLOGICALS, INJECTABLE	X	X		X	X
SAMPLE PROCESSOR, AUTOMATIC, BLOOD	X	X			

Table 2-5. Initial List of Equipment Items for Biomedical and Biological FPEs, Contd

EQUIPMENT ITEMS	USING F.P.E.'S BIO-MEDICINE	SMALL VERTE-BRATES	CELLS & TISSUES	PLANTS	INVERTE-BRATES
SPECIMEN PREPARATION (CONT'D)					
SLIDES, MICROSCOPE	X	X	X	X	X
SLIDE STAINER, AUTOMATIC	X	X	X	X	X
SQUIBBS (PLANT GROWTH ARRESTER) (25/PK)				X	
SQUIBB FIRING MECHANISM				X	
STAINS, ASSORTED, HISTOLOGICAL		X	X	X	X
SUTURE MATERIAL, MONOFILAMENT		X			
SWABS, COTTON (4/TUBE)	X	X	X	X	X
TEMPERATURE BLOCK 56 DEG.C	X	X	X		X
TIMER, INTERVAL	X	X	X	X	X
TUBES, MICROHCT, HEPARINIZED	X	X	X		X
TUBES, MICROHCT, PLAIN	X	X	X		X
WRIGHT BUFFER	X	X	X		X
WRIGHT STAIN	X	X	X		X
SPECIMEN STORAGE					
BAGS, PLASTIC, SEALABLE, LARGE	X	X	X	X	X
BAGS, PLASTIC, SEALABLE, SMALL	X	X	X	X	X
DRY STORAGE CONTAINER (ROOM TEMP)	X	X	X	X	X
FIXATIVE, ETHANOL		X	X		X
FIXATIVE, FORMALIN		X	X		X
FIXATIVE, TISSUE, EXPERIMENT SPECIFIC	X	X	X	X	X
FIXATIVE, ZENKERS SOLUTION	X	X	X		X
FREEZER, CRYOGENIC (LN2) (OPTIONAL)	X	X	X	X	X
FREEZER, LOW TEMPERATURE -80C	X	X	X	X	X
FREEZER UNIT -10C	X	X	X	X	X
INCUBATOR, (MINI)	X	X	X	X	X
REFRIGERATOR	X	X	X	X	X
SPECIMEN VIALS	X	X	X	X	X
DATA ACQUISITION/STORAGE					
ADAPTER, MICROSCOPE-CAMERA	X	X	X	X	X
CAMERA, 35 MM	X	X	X	X	X
CAMERA, POLOROID	X	X	X	X	X
CAMERA, VIDEO, COLOR	X	X	X	X	X
CAMERA, VIDEOTAPE	X	X	X	X	X
LOG BOOKS	X	X	X	X	X
TAPE, MAGNETIC, INSTRUMENTATION	X	X	X	X	X
TAPE RECORDER		X	X	X	X
ON BOARD SPECIAL ANALYSIS, REQ'D EQUIP.					
ANALYZER, BLOOD GAS, PH, PCO2, PO2	X	X			
COUNTER, COLONY, MANUAL			X	X	X
DISPLAY, CRT, ELECTROPHYSIOL.	X	X			X
ELECTROCARDIOGRAPH	X	X			
LABSTIX (GLU,ALB,BLOOD,PH,KETONE)	X	X			
HEMACYTOMETER	X	X	X		X
HEMOGLOBINOMETER	X	X			
METABOLIC GAS ANALYZER, CELLULAR			X	X	
METABOLIC GAS ANALYZER, PULMONARY	X	X			
MICROSCOPE, COMPD	X	X	X	X	X
SPIROMETER (PART OF METAB. ANALYZER)	X				
PH METER, CELLS/TISSUES MEDIA			X	X	
MAINTENANCE/CLEANUP					
DISINFECTING SWABS (PREPACKED TOWELS)	X	X	X	X	X
LINERS, DISSECTING BOARD (50/PKG)		X			X
LINERS, GLOVE BOX (50/PKG)		X	X	X	X
PORTABLE AIRFLOW WORK SURFACE	X	X	X	X	X
STERILIZER, TOOL (BACTECINERATOR)	X	X	X	X	X
TOWELS, DRY, DISPOSABLE	X	X	X	X	X
TOWELS, PREMOISTENED, ZEPHIRAN CL	X	X	X	X	X
VACUUM CLEANER (PART OF ECS AIR RETURN)		X	X	X	X
WASTE STORAGE CONTAINER	X	X	X	X	X
ENVIRONMENTAL CONTROL/LIFE SUPPORT SYSTEM					
ECS PACKAGE					
AIR CIRCULATOR (BLOWER SYSTEM)		X	X	X	X
COOLER, FLUID LOOP		X	X	X	X
FILTER, ACTIVATED CHARCOAL		X	X	X	X
FILTER UNIT, HEPA		X	X	X	X
HEATER, FLUID LOOP		X	X	X	X
OXYGEN MANIFOLD AND METERING SYSTEM	X	X	X	X	X
OXYGEN SUPPLY, PRESSURIZED CYLINDERS	X	X	X	X	X
THERMOCOUPLES	X	X	X	X	X
HOLDING UNIT MODULE					
ANIMAL WATERING DEVICE		X			
CAGE, SMALL VERTEBRATES		X			
CLINOSTAT				X	
COMMON CAGE MODULE		X	X	X	X
FEEDER, VERTEBRATE		X			
GAS MONITOR (CO2,O2)		X	X	X	X
HOLDING CHAMBER, CELLS/TISSUES			X		
HOLDING CHAMBER, INVERTEBRATES			X		X
LIOH CARTRIDGES		X			X
PLANT WATERING SYSTEM, AUTO				X	
MEDIA, TISSUE CULTURE			X		
WASTE MANAGEMENT SYSTEM, VERTEBRATES		X			

Table 2-6. Approximate Equipment List for the Biomedical and Biological COL Conceptual Layouts

EQUIPMENT ITEMS	USING F.P.E.'S*						APPROXIMATE E.I. PROPERTIES*		
	BIO-MEDICINE	SMALL VERTE-BRATES	CELLS & TISSUES	PLANTS	INVERTE-BRATES	SM. VERT. AS MAN SURROGATES	WEIGHT, KG	VOLUME, DM^3	POWER, WATTS
AIR PARTICLE SAMPLER	X	X	X	X	X	X	2.7	14.2	50
BLOOD GAS ANALYZER	X	X				X	15.9	42.5	150
CAGE, SMALL VERTEBRATES (8 INCL.)		X				X	27.2	-	96
CAGE MODULE, SM. VERT.		X				X	18.1	253.8	0
CAMERA, POLOROID (INCL. ACCESS.)	X	X	X	X	X	X	11.3	2.8	0
CAMERA, VIDEO, COLOR	X	X	X	X	X	X	9.1	28.3	100
CAMERA, VIDEO, BLACK/WHITE	X	X	X	X	X		5.1	2.8	10
CAMERA, 35MM	X	X	X	X	X	X	0.7	5.6	0
CENTRIFUGE, MICROCHEMICAL/HCT	X	X	X		X	X	8.2	13.3	25
CLINOSTAT				X			10.0	88.9	10
COLONY COUNTER			X	X	X		1.4	17.0	50
COUPLERS	X	X			X	X	0.5-3	2-10	5-30
DRY STORAGE CONTAINER (ROOM TEMP.)	X	X	X	X	X	X	2.3	42.5	0
ECS, SMALL VERTEBRATES		X				X	25.5	60.9	60
ELECTROCARDIOGRAPH (RECORDER)	X	X				X	2.7	5.6	5
EQUIPMENT RESTRAINTS	X	X	X	X	X	X	0.5	2.8	0
FREEZER, LOW TEMPERATURE	X	X	X	X	X	X	11.3	2.8	150
GAS MONITOR (CO2, O2)		X	X	X	X	X	1.2	1.1	1
GAS SUPPLY VESSELS & LINES	X						13.6	43.9	0
GLOVE BOX (SHROUD TYPE)		X	X	X	X	X	2.3	0	0
HOLDING UNIT, C/T			X				22.7	188.0	50
HOLDING UNIT, INV. (INCL. CONTAINERS)					X		29.9	188.0	50
HOLDING UNIT, PLANTS				X			22.7	188.0	500
HOMOGENIZER, .2 TO 50 ML		X	X	X	X		3.6	14.2	150
INCUBATOR, 37C (MINI)	X	X	X	X	X	X	4.5	42.5	50
KIT, ANIMAL PHYSIOLOGY		X				X	1.5	2.0	0
KIT, CLEAN-UP	X	X	X	X	X	X	1.5	5.1	0
KIT, GENERAL TOOL	X	X	X	X	X	X	4.5	14.2	0
KIT, HEMATOLOGY	X	X				X	4.0	5.9	0
KIT, HISTOLOGY		X		X	X	X	1.0	1.1	0
KIT, HUMAN PHYSIOLOGY	X						3.0	8.0	0
KIT, MICROBIOLOGY	X	X	X	X	X	X	3.0	3.1	0
KIT, MICRODISSECTION		X	X	X	X	X	1.0	2.0	0
KIT, PLANT MANAGEMENT				X			1.8	2.0	0
KIT, VERTEBRATE MANAGEMENT		X				X	3.0	5.9	0
LOG BOOKS	X	X	X	X	X	X	0.5	1.4	0
LYOPHILIZER, SPACE VACUUM		X	X	X	X		4.5	22.7	0
MASS MEASUREMENT DEVICE		X			X	X	4.5	14.2	15
METABOLIC ANALYZER, CELLULAR			X	X			6.8	14.2	50
METABOLIC GAS ANALYZER, PULMONARY	X	X					22.7	113.3	50
MICROSCOPE, COMPD	X	X	X	X	X	X	6.8	22.7	25
MICROSCOPE, DISSECTING		X	X	X	X	X	9.1	28.3	63
OSCILLOSCOPE (CRT)	X	X			X	X	18.1	28.3	20
PH METER			X	X			1.8	5.7	20
REFRIGERATOR	X	X	X	X	X	X*	9.1	56.6	15
SAMPLE PROCESSOR, AUTO. BLOOD	X	X				X	4.5	2.8	50
SLIDE STAINER	X	X	X	X	X	X	6.8	42.5	50
STERILIZER, TOOL (BACTECINERATOR)	X	X	X	X	X	X	1.4	2.8	110
TAPE RECORDER		X	X	X	X	X	4.5	3.1	20
TEMP. BLOCK	X	X	X		X	X	1.8	1.4	100
TAPE, MAGNETIC	X	X	X	X	X	X	2.3	2.8	0
TIMER, EVENT	X	X	X	X	X	X	0.2	1.0	0
WASTE STORAGE CONTAINER	X	X	X	X	X	X	0.5	28.3	0
WATERING DEVICE, ORGANISM		X				X	4.5	28.3	0
WORK SURFACE, AIRFLOW	X	X	X	X	X	X	0.5	2.8	0

*USING [illegible] AND WEIGHT, POWER & VOLUME OF THE EQUIPMENT ITEMS WERE CONTINUALLY REVISED AND UPDATED DURING THE STUDY. FOR FINAL LISTINGS AND VALUES, SEE [illegible] OF THIS VOLUME AND THE E.I. SPECIFICATION SHEETS IN VOLUME III.

Table 2-7. Initial List of Equipment Items for Candidate in MSI Experiments

REQUIRED EQUIPMENT ITEMS (E.I.'S)	1 Effects of Space Flight Environment on Sensory Processes	2 Effects of Space Flight Environment on Psychomotor Functions	3 Cargo Handling Capabilities	4 Assembly, Deployment, Maintenance & Repair Capabilities	5 Attached Teleoperator Manual Controllability	6 Free-Flying Teleoperator Remote Controllability	7 Effects of Space Flight Environment on Individual & Group Dynamics	8 Locomotion & Restraint Capabilities	9 Effectiveness of End Effector Designs	10 Off-Duty Activity & Facilities	11 Evaluation of Miniature Accelerometers—to Assess Effects of Stress & Fatigue	12 Urine & Feces Collection, Measurement & Sampling Systems	13 Inflight Determination of Bone Mineral Content	14 Compact Respiratory Measurement System	15 Automated Clinical Chemical Analyzer	16 System to Preserve Biological Materials	17 Medical Aspirator	18 Intravenous Fluid Administration Device	19 Blood Cell Counter
Accelerometer			x		x	x					x								
Accelerometer Coupler			x		x	x					x								
Accommodation Range Tester	x						x												
Airlock, EVA															x	x		x	x
Anomalascope	x						x												
Audio Stereo Headset	x						x												
Audio Tone Source, Portable	x						x												
Audiometer	x						x												
Bags, Plastic, Permeable															x	x		x	x
Bench, Laminar Flow			x	x															
Biobackpack, Micro	x	x	x	x	x	x	x	x		x	x								
Camera, Cine			x	x	x	x	x	x	x	x									
Camera, Still			x	x	x	x	x	x	x	x									
Camera, Video B&W		x	x	x	x	x	x	x	x	x						x	x	x	
Camera, Video Color			x	x	x	x	x	x	x	x									
Camera Controller			x	x			x	x		x						x	x	x	
Computer, Digital	x	x	x	x	x	x	x	x	x	x	x					x	x	x	
Console, Behavioral Measurements	x	x					x			x									
Converter, A-D	x	x	x	x	x	x	x	x		x	x								
Crew Mobility Aids			x	x				x		x									
Crew Restraints		x	x	x			x	x		x	x	x	x	x	x		x	x	
Data Control Unit, TV		x	x	x			x			x									
Data Management System, Plotter & Control Module	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x
Display/Keyboard, Portable			x	x	x	x	x									x			
Dynamometer, Grip		x					x												
ECG Coupler	x	x	x	x	x	x	x	x		x	x								
EEG Coupler	x	x					x			x	x								
Electrophysiology Console	x	x	x	x	x	x	x	x		x	x								
Electrophysiology Display	x	x	x	x	x	x	x	x		x	x								
Electrophysiology Monitor	x	x	x	x	x	x	x	x		x	x								
Electrophysiology Receiver	x	x	x	x	x	x	x	x		x	x								
Filters, Video			x	x			x	x		x						x	x	x	
Flicker Fusion Apparatus	x						x												
Gas Supply, Assorted															x	x		x	x
Generator Signal											x								
Harness, Small Wire	x	x	x	x	x	x	x	x		x	x								
Kit, Behavioral Measurements I	x	x					x			x									
Kit, Behavioral Measurements II	x	x					x			x									
Limb Board, Motor or Manual	x						x												
Log Books							x									x	x	x	
Manipulator, Remote					x	x			x										
Meters, Assorted	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x
Microphone	x	x					x			x									
Mirror, Revolving	x						x												
Mirror Mount - Commutator			x	x			x	x		x						x	x	x	
Monitor, Video			x	x	x	x	x	x	x	x									
Orthorater	x						x												
Oscillator, VDC	x	x	x	x	x	x	x	x		x	x								
Oscilloscope											x								
Paper, Recording	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x
Patchboard System	x	x	x	x	x	x	x	x		x	x								
Pegboard, Purdue		x					x												
Pegboard, Santa Ana		x					x												
Perceptual Motor Perf. Tester		x					x												
Position Estimation Control		x					x												
Power Supply			x	x	x	x	x	x	x	x						x	x	x	
Psychomotor Performance Console		x					x												
Psychomotor Rotating Disks		x					x												
Radiation Waste System															x	x		x	x
Receiver, EXG	x	x	x	x	x	x	x	x		x	x								
Recorder, Tape, Voice	x	x					x			x									
Room, Private							x			x									
Sensors, Assorted	x	x	x	x	x				x	x	x								
Signal Conditioners	x	x	x	x	x	x	x		x	x	x								
Sound Level Meter	x	x					x			x									
Steadiness Tremor Apparatus		x					x												
Sterilizer, Autoclave															x	x		x	x
Storage, General	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x
Tape, Video			x	x			x	x		x						x	x	x	
Target, Landolt Ring App.	x						x												
Taskboard, Force/Torque		x					x												
Taskboard, Maint./Gross C.		x					x												
Taskboard, Position Repro.		x					x												
Taskboard, Resp. Orientation		x					x												
Taskboard, Visual React. Time		x					x												
Timer, Event		x	x	x			x												
Timer, Integral Equip.			x	x															
Vision Tester	x						x												
Vision Tester, Howard Dolman	x						x												
Vision Tester, Amer. Optical	x						x												
Experiment Specific Equipment		x			x	x	x		x		x	x	x	x	x	x			x

listed as high-priority experiments should not have been so placed. The experiments are being considered as candidates for the COLs with a baseline mission duration of only seven days. In view of the successful performance of the first Skylab astronaut crew on their 28-day mission with no apparent, or at least, publicized degradation of their sensory or psychomotor processes, it was felt that no degradation would be detectable over the baseline seven-day mission. NASA agreed with this recommendation, and Experiments 1 and 2 were considered only in a secondary manner in further selection of research equipment and COL design. The equipment items to satisfy the various experiments are listed along the left edge of Table 2-7.

The number of equipment items in this list was unwieldy and too large for inclusion in the COLs. An initial reduction in equipment requirements was obtained by comparing the various methods available for performing each research function, as identified in the functions inventory, and selecting the method and equipment that was most appropriate to the mode of operation of the COLs. Factors considered were costs, scientific validity of the resulting research, and commonality of equipment. Some equipment items were sized for the larger dedicated laboratories and smaller versions were necessary for the COLs. Other items were deleted because their function was assumed to be provided by the supporting spacecraft.

2.2.2 MSI CANDIDATE EQUIPMENT GROUPING. The resulting list of equipment items was then grouped into categories by general function, as shown in Table 2-8. Most equipment within each group will be required whenever that general function is required. A given COL can thus be efficiently assembled by selecting the required equipment groups. It should be noted that a considerable weight saving can be achieved if the supporting spacecraft data management capability can be used instead of the data management equipment group indicated, and that this will quite likely be done.

The behavioral measurements equipment group contains the equipment required to measure the sensory and psychomotor processes. This equipment would normally be used in conjunction with the data management equipment group to provide oscilloscope display, computer control, and the capability for automatic recording and scoring of the tests. The environmental monitor has been placed in the behavioral measurements equipment group to satisfy the requirement for environmental monitoring during sensory processes testing (e.g., monitoring noise levels during audiometer tests). All equipment in this group is IMBLMS developed and should require little modification.

Data management equipment provides most equipment for automatic or operator control of the experiments, display of experiment procedures and stimuli, and recording of appropriate results. All equipment is IMBLMS developed and should interface well with the equipment described previously. An interesting feature of the record and display matrix assembly is its capability for accepting tape cassettes to program the computer for a desired test, and the recording of the subject's test results on his own individual cassette for later ground analysis.

Table 2-8. Preliminary MSI Equipment Groupings

EQUIPMENT ITEMS	WEIGHT kg	POWER watts	DIMENSIONS OR VOLUME STOWED dm or dm^3	DIMENSIONS OR VOLUME UNSTOWED dm or dm^3	SOURCE
	BEHAVIORAL MEASUREMENTS				
Vision Tester	18.1	10	2.5×4.3×4.6	2.5×4.3×5.6	IMB
hood					
bite board					
Audiometer	15.9	40	2.7×5.1×5.1		"
headset					
Audiometer/Vision Control Assembly	5.4	4	2.6×2.6×2.6		"
Psychomotor Tester	4.5	5	1.3×2.7×2.7		"
critical task control panel					
Environmental Monitor	6.8	10	2.0×2.7×3.0	1.3×2.7×6.1	"
	50.7				
	DATA MANAGEMENT*				
Storage Scope with Grid (Oscilloscope)	18.1	100	2.7×2.7×5.1		IMB
System Input Module	11.3	13	2.7×5.1×2.7		"
Integrated Display Module (A/N TV)	16.3	117	2.7×2.7×5.1		"
Record and Display Matrix Assembly	21.3	100	1.8×5.1×5.1		"
Main Computer (½ the IMB computer)	13.2	125	1.8×2.7×2.7		"
Data Tape Cassette, 1 for each crewman and each software package	-	-	-		"
	80.2				
	AUDIO-VISUAL MEASUREMENTS				
Video Camera, Color	22.7	100	28.3 dm^3		SKY
power cords					
remote cables					
Videotape	5.1	10	2.8 dm^3		"
Video Tape Recorder	22.2	80	4.6×2.8×4.0		SONY MANUAL
Lamps, Photographic	0.9	150	7.1 dm^3		SKY
Lens, Assorted Sizes	4.5	0	5.7 dm^3		"
Mounts, Camera	2.3	0	1.4 dm^3		"
Microphone	0.5	0	0.1 dm^3		"
Voice Tape Recorders	4.5	15	2.8 dm^3		"
Magnetic Tape, Voice Recorders	1.1	0	0.4 dm^3		"
Controller, Video Camera	4.5	200	14.2 dm^3		INV
	68.3				
	PHYSIOLOGICAL MEASUREMENTS				
Electrodes, EXG, Disposable	negl.	0	0.3 dm^3		SKYLAB
Harness, Electrophysiology	0.45	0	2.8 dm^3		"
Respirometer, Strain Gage	0.05	0	1.1 dm^3		"
Spirometer Mouthpieces	0.05	0	2.8 dm^3		"
Thermistor, Deep Body Temp.	0.05	0	0.0 dm^3		INV
Coupler, EMG	0.05	1	0.0 dm^3		SKYLAB
Coupler, Strain Gage	0.05	1	0.3 dm^3		"
Coupler, Thermistor	0.05	1	0.3 dm^3		"
Metabolic Gas Analyzer, Pulmonary	22.68	50	271.9 dm^3		"
	23.43				
	EXPERIMENT SPECIFIC				
Experiment Specific Taskboards, Simulators, Supporting Tool Kits, Remote Manipulators, etc.	tbd	tbd	tbd		

*Availability of centralized data management equipment on the supporting spacecraft can significantly reduce this equipment group.

The audio-visual measurements equipment provides the capability for non-interference measurements when required. This is the primary measurements equipment for studies of individual and group dynamics as well as astronaut performance studies where task completion times or body motions are a primary measurement. It contains its own tape recorders, so it can be used independent of the data management equipment as discussed later.

The physiological measurements equipment is used when the physiological status of the test subject is to be monitored. For example, when various cargo-handling techniques are under evaluation, a primary consideration is the energy expenditure required of the test subject while using each technique. The metabolic gas analyzer indicated here is a stripped-down version of the Skylab analyzer.

The final group of equipment is experiment-specific. Its content will depend on the experiment(s) to be completed on a given mission.

2.3 LIFE SUPPORT AND PROTECTIVE SYSTEMS RESEARCH AREAS AND EQUIPMENT SELECTION

2.3.1 CANDIDATE EQUIPMENT SELECTION. The areas of research to be performed for life support and protective systems (LSPS) were divided into 12 categories as listed below. They are essentially types of potential experiments and are listed in order of priority, as established by NASA at the beginning of this study.

1. Water Recovery Methods and Components.
2. Waste Management Methods and Components.
3. Protective Clothing and Advanced Space Suit Assemblies.
4. Carbon Dioxide Collection Methods and Components.
5. Advanced Cooling System Methods and Components.
6. Atmospheric Supply Methods and Components.
7. Advanced Two-Gas Atmosphere Supply and Control Subsystem.
8. Advanced Trace Contaminant Control and Monitoring Subsystem.
9. EVA Suit and Biopack.
10. Food Storage, Preparation, and Feeding Methods.
11. Oxygen Regeneration Methods and Components.
12. Whole Body Shower.

The first step in determining equipment requirements was to review the life sciences payload definition functions inventory and choose those functions required for each of the 12 categories of experiments. For each function in the functions inventory, the specific equipment needed to perform the function is listed. Thus, the functions could be used to obtain a list of equipment pertinent to the LSPS experimentation. The resulting list of equipment is shown in Table 2-9, which indicates the equipment items needed for each of the 12 experiment categories. Equipment shown in the table was too numerous for use in LSPS COLs, so the list was screened for items that could be eliminated without severely reducing the research capability of the COLs. In many cases, the equipment in Table 2-9 was based on a larger laboratory concept where complete analysis of specimens is performed in space and the laboratory is independent of the supporting vehicle. The COL concept is not compatible with such guidelines. The method used in screening the equipment for possible candidates for elimination involved the following criteria.

a. Analysis of specimens will be performed on the ground subsequent to the flight where possible. (For example, water and solids analysis for constituents as well as for micro-organisms will be performed on the ground. If inflight analysis is to be performed, it was assumed that it would be provided as part of the test apparatus. For example, if water conductivity or pH is to be measured, these sensors were assumed to be included in the test apparatus rather than in the COL.)

b. Data management functions and equipment were assumed to be provided by the supporting spacecraft data management subsystems.

c. The electrical power subsystem was assumed to be provided by the supporting vehicle.

d. Coolant was assumed to be provided by the supporting vehicle.

e. Equipment for experiments involving nuclear radiation was assumed to be a part of the test apparatus and not the LSPS COLs.

f. Equipment and electrical power for lighting in the general vicinity of the COLs were assumed to be provided by the supporting vehicle.

2.3.2 LSPS CANDIDATE EQUIPMENT GROUPS. By reviewing the equipment required for each experiment category and considering the types of experiment apparatus to be tested, four potential groups of COL equipment emerged from the study. These were designated as:

I. Liquid Handling Equipment. To support tests in the experiment categories of:

1 Water Recovery Methods and Components
2 Waste Management Methods and Components
5 Advanced Cooling System Methods and Components
6 Atmospheric Supply Methods and Components

II. Crew Interfacing Equipment. To support tests in the experiment categories of:

3 Protective Clothing and Advanced Space Suit Assemblies

Table 2-9. Initial Unlimited List of Equipment Items for the LSPS Experiment Categories

EQUIPMENT ITEMS	EXPERIMENT CATEGORIES 1 Water Recovery	2 Waste Management	3 Protective Clothing & Suits	4 CO_2 Collection	5 Cooling Systems	6 Atmosphere Supply	7 Atmosphere Control	8 Trace Contam. Control	9 EVA Suit Biopack	10 Food & Feeding	11 O_2 Regeneration	12 Whole Body Shower
Air Lock - EVA			x						x			
Analyzer, Atomic Absorption Spectrophotometer								x		x		
Analyzer, Infrared Absorption	x		x	x								
Analyzer, General Spectrophotometer	x	x		x		x	x	x		x	x	
Analyzer, Micro-organism, Automatic I.D.	x	x										
Analyzer, Conductivity	x											
Atmospheric Sampling Manifold System				x		x	x	x			x	
Badges, Radiation, Standard Film								x				
Bags, Permeable Plastic		x										x
Bicycle Ergometer			x						x			
Bottles, Cells and Tissues	x	x			x							x
Camera, Cine												x
Camera, Still												x
Camera, Video, Black and White												x
Camera, Video, Color	x	x	x						x			x
Chemicals				x				x			x	
Compactor, Solids		x								x		
Computer, Digital	x	x	x	x	x	x	x	x	x		x	x
Cooler, Thermoelectric			x					x	x			x
Counter, Colony, Manual	x											
Crew Mobility Aids			x						x			x
Crew Restraints			x						x			x
Data Management Buses	x			x	x	x	x	x			x	
Data Management Plotter/Printer	x	x		x	x	x	x	x			x	x
Data Management Control Station	x		x	x	x	x	x	x	x		x	x
Data Management Remote Instrumentation Modules	x			x	x	x	x	x			x	
Data Management Wide Band & TV Unit	x			x	x	x	x	x			x	
Developer, Film								x				
Display - Keyboard				x	x	x	x	x			x	x
Electrometer				x		x	x	x			x	
Feeder, Liquid, Automatic	x	x										x
Flowmeters	x	x	x			x	x		x	x		x
Flowmeter Couplers	x	x	x			x	x		x	x		x
Filters, Chemical	x	x		x							x	x
Frig. (Refrigerator)	x	x								x		x
Gas Analyzer, CO_2		x		x		x	x	x			x	
Gas Analyzer, Gas Chromatograph	x	x	x	x		x	x	x	x	x	x	
Gas Analyzer, Mass Spectrometer, Research		x		x		x	x	x		x	x	
Gas Analyzer, Mass Spectrometer, Special	x	x		x		x	x	x			x	
Gas Analyzer, O_2			x					x	x			
Gas Analyzer, Relative Humidity				x				x			x	
Gas Supply	x	x		x		x	x	x		x	x	x
Gas Metering & Calibration Unit				x		x	x	x			x	
Holding Unit, Cells/Tissues	x	x										x
Indicator, Atmospheric O_2								x				
Ionization Detector, Flame	x	x		x		x	x	x		x	x	
Kit, Chemical	x	x	x	x		x	x		x	x	x	x
Kit, Clean-up	x	x	x	x	x	x	x	x	x	x	x	x
Kit, Microbiology	x	x	x						x			x
Kit, General Tool	x	x		x	x	x	x	x		x	x	x
Leak Detector		x	x			x	x	x	x			
Manifold, Vacuum	x	x		x							x	x
Maintenance Task Simulator			x						x			
Mass Measurement Device, Macro	x	x				x	x			x		x
Mass Measurement Device, Micro	x											
Media, Dehydrated	x	x										x
Media, Prepared										x		
Meters	x	x		x	x	x	x	x		x	x	x
Microscope, Compound	x	x	x						x			x
Monitor, Video												x
Paper, Recording	x	x		x	x	x	x	x			x	x
pH Meter	x									x		x
Portable Life Support System			x						x			
Power Supply												x
Pressure Suit Connector			x						x			
Pressure Suit Manipulation Aids			x						x			
Radiation Detector, Dosimeter								x				
Radiation Detector, General								x				
Radiation Waste System		x										x
Recorder, Multichannel Biomedical	x	x		x	x	x	x	x			x	x
Sensors	x	x		x	x	x	x	x		x	x	x
Shroud, Environmental		x				x	x	x				
Signal Conditioners	x	x	x	x	x	x	x	x	x	x	x	x
Sterilizer, Autoclave		x										x
Storage, General	x			x	x	x	x	x			x	x
Storage, Film								x				
Stove	x											
Temperature Sensors, Body										x		
Temperature Sensors, Infrared			x					x	x	x		
Thermocouples			x					x	x			x
Thermometers										x		
Transducer, Plethysmograph	x	x		x	x	x	x	x			x	x
Trash Can		x								x		
Valves	x	x		x	x	x	x	x			x	x
Voltmeter				x		x	x	x			x	

9 EVA Suit and Biopack
2 Waste Management Methods and Components (some experiments)
12 Whole-Body Shower

III. Gas Handling Equipment. To support tests in the experiment categories of:

4 CO_2 Collection Methods and Components
7 Advanced Two-Gas Atmosphere Supply and Control Subsystem
8 Advanced Trace Contaminant Control and Monitoring Subsystem
11 Oxygen Regeneration Methods and Components

IV. Feeding System Equipment. To support tests in the equipment category of:

10 Food Storage, Preparation, and Feeding Methods

The equipment in Table 2-10 is listed according to these general groups. The liquid-handling equipment (I) and the gas-handling equipment (III) are practically identical. This equipment would be incorporated into a test bench for general support of tests on liquid- or gas-handling devices. The facilities would include electrical power connections, vacuum lines, coolant connections, liquid supply and storage tanks, gas supply vessels, gas analysis equipment, a refrigerator for biological samples, various kits, and photographic equipment. The devices to be tested on these benches will in some cases be reduced in capacity from the actual capacity of interest for use in a future operational application. In general, the apparatus tested was expected to occupy a maximum volume of about 0.2 m^3 (7.06 ft^3).

Crew interfacing equipment (II) differs from liquid- and gas-handling COLs in that a crewman is integrally involved in the testing. An area is required for this purpose, with the supporting equipment housed in a console-type structure adjacent to the test area. Typical experiments include tests on urinals, commodes, crew clothing, liquid-cooled garments, hard and soft pressure suits, portable life support systems, and the whole-body shower. Since the tests vary considerably, a smaller amount of generally applicable equipment could be identified for these types of experiments. Much of the support equipment will be specific to the individual experiments. General equipment includes cameras, gas analysis equipment, various kits, a portable voice recorder, and various sensors. A bicycle ergometer, an air lock, and metabolic analysis equipment are required for some experiments. These are considered experiment-specific equipment items.

The last group of equipment (IV) is entirely devoted to the support of tests in a single experiment category — that of food storage, preparation, and feeding methods. The equipment shares some similarity to both the liquid-handling and the crew-interfacing equipment. A crewman will be integrally involved in some tests and a test bench type of structure is required for the various experiments. However, the bench is expected to be different from the benches used with gas- and liquid-handling equipment. It must

Table 2-10. Summary of General Purpose LSPS Equipment

Equipment Items (E.I.'s)	Group I Experiments Liquid Handling Equip.			Group II Experiments Crew Interfacing Equip.			Group III Experiments Gas Handling Equip.			Group IV Experiments Feeding System Equip.		
	kg	watts	dm^3	kg	watts	dm^3	kg	watts	dm^3	kg	watts	dm^3
1. Camera, Cine	5.0	13	5.0	5.0	13	5.0				5.0	13	5.0
2. Camera, Still	1.8	0	2.0	1.8	0	2.0				1.8	0	2.0
3. Camera, Video, Black & White	4.4	15	3.0	4.4	15	3.0				4.4	15	3.0
4. Crew Mobility Aids	2.3	0	2.8	2.3	0	2.8	2.3	0	2.8			
5. Crew Restraints	4.0	0	10.0	4.0	0	10.0	4.0	0	10.0	4.0	0	10.0
6. Display, Numeric	1.0	2	2.0	1.0	2	2.0	1.0	2	2.0	1.0	2	2.0
7. Electrical System	10.0	20	10.0	10.0	20	10.0	10.0	20	10.0	10.0	20	10.0
8. Film	2.8	0	2.5	2.8	0	2.5				2.8	0	2.5
9. Film Cabinet	9.1	0	5.6	9.1	0	5.6				9.1	0	5.6
10. Flowmeters	2.0	8	2.0				2.0	8	2.0	2.0	8	2.0
11. Gas Chromatograph	20.0	300	60.0	20.0	300	60.0	20.0	300	60.0			
12. Gas Supply Vessels	11.5	0	36.0				11.5	0	36.0			
13. Infrared Gas Analyzer							11.3	50	42.6			
14. Kit, Chemical Sampling	4.5	0	14.2	4.5	0	14.2	4.5	0	14.2	4.5	0	14.2
15. Kit, Clean-Up	2.0	0	5.0	2.0	0	5.0	2.0	0	5.0	2.0	0	5.0
16. Kit, General Tool	4.5	50	14.2	4.5	50	14.2	4.5	50	14.2	4.5	50	14.2
17. Lamp, Portable Photo	6.3	150	6.0	6.3	150	6.0				6.3	150	6.0
18. Leak Detector							9.1	10	28.3			
19. Liquid Tanks (wet weight)	16.5	0	16.5				16.5	0	16.5	16.5	0	16.5
20. Mass Measurement Device	5.0	10	20.0				5.0	10	20.0	5.0	10	20.0
21. Mass Spectrometer	10.0	10	6.0	10.0	10	6.0	10.0	10	6.0			
22. Multimeter	6.5	60	9.0	6.5	60	9.0	6.5	60	9.0	6.5	60	9.0
23. Plumbing	10.0	0	6.0				10.0	0	6.0	10.0	0	6.0
24. Recorder, Voice				1.0	10	2.0				1.0	10	2.0
25. Refrigerator	9.1	15	42.5				9.1	15	42.5	9.1	15	42.5
26. Sensors (incl. couplers)	2.0	4	2.0				2.0	4	2.0	2.0	4	2.0
27. Shroud, Environmental	4.5	0	5.7				4.5	0	5.7			
28. Timer, Event	0.5	5	0.5	0.5	5	0.5	0.5	5	0.5	0.5	5	0.5
29. Trash Container	1.0	0	28.3	1.0	0	28.3	1.0	0	28.3	1.0	0	28.3
30. Vacuum Cleaner										2.3	100	10.0
31. Vacuum Manifold System	9.1	0	5.6				9.1	0	5.6			
TOTALS (lbs) (ft^3)	165.4 (364.7)	662	317.0 (11.19)	96.7 (213.2)	635	188.1 (6.64)	156.4 (344.9)	544	369.2 (13.04)	111.3 (245.4)	462	218.3 (7.71)
FOR ALL GROUPS (Total of all 31 E.I.'s)	189.1 (417.0)	832	399.9 (14.12)									

accommodate the crewman as he tests feeding devices. Typical test items include food trays with integral temperature control, liquid dispensers, special crew restraints for eating, utensils, food debris clean-up devices, etc.

Preliminary weight, power, and volume values for the equipment within each of the four candidate equipment groups are given in Table 2-10. Total power values shown in the table are merely the totals of all the equipment if operating simultaneously. This should never occur, and the actual power required for the COLs should be substantially less than indicated by the totals. Further analyses of weight, power, and volume of the COLs is the subject of later studies during this contract. However, the totals indicated in Table 2-10 were used as a general guide to indicate that the LSPS COLs would not be out of the range of reasonable weight, power, and volume allowances.

SECTION 3

CARRY-ON LABORATORY CONCEPTUAL LAYOUTS
(TASK B)

This section summarizes the major activity performed during Task B of the COL program, which was the generation of conceptual layouts for the various COLs. Equipment lists developed during the Task A equipment definition phase served as the basis for these layouts and were updated as required during Task B. COL weight, power, and volume guidelines described in Section 1.4 were used to scope the activity, but were not used to impose strict or limiting constraints on the initial set of layouts.

3.1 GENERAL APPROACH TO THE DEVELOPMENT OF CONCEPTUAL LAYOUTS

A number of layout parameters were considered during Task B (Table 3-1). Several layouts were often drawn for the same FPE, with different options of these parameters selected to obtain comparisons between the resulting layout configurations. The general layout parameters considered for each FPE are summarized in the following paragraphs. The options considered within each heading, such as use of standardized racks for the COL compared to the use of a custom-configured COL, are discussed in Section 3.2.

Table 3-1. Layout Parameters Considered During Task B

	Layout Parameters				
FPE	Module Configuration, Standardized Rack or Custom	Crew Interface, Standing and/or Seated	Isolation from the Crew, Glove Box, Open, etc.	ECS, Open to Crew Compartment or Closed	Organism Holding Unit Size, Standardized or Custom
Biomedicine	x	x	x	x	
Vertebrates	x	x	x	x	x
Cells & Tissues	x	x	x	x	x
Invertebrates	x	x	x	x	x
Plants	x	x	x	x	x
MSI	x	x			
LS/PS	x	x			

After a set of parameters to be used for any FPE was selected, a layout of the potential COL was drawn. In all, 26 layouts were prepared. On each layout drawing, the parameters used in the layout were indicated. (See Fig. 3-1, pg. 3-8, for example.) These are indicated by the code numbers in the circles at the right, lower corner of each drawing. The code numbers differ for the biomedicine/biology layouts, the MSI layouts, and the LSPS layouts and are defined in the individual sections that describe each FPE.

Each layout drawing also contains estimates of the weight and volume associated with the layout, broken into general-purpose research equipment (GPRE), the module to contain this equipment, the experiment-specific equipment (ESE), and the module to contain the ESE. The weight of the experiment-specific equipment is not known at this time and is therefore generally indicated as TBD or a blank on the drawings.

3.2 BIOMEDICINE AND BIOLOGY COL LAYOUTS

The initial guidelines used to develop Biomedicine and Biology COL conceptual layouts included:

a. Emphasize modular design, common equipment, and interchangeability between the various COLs.

b. Provide interfaces for experiment-specific functions (e.g., the LBNP).

c. Design the vertebrate COL to support both human-emphasis research and basic biological research.

d. Consider the use of both open and closed environmental control systems, with or without isolation of the organisms from the crew compartment.

COL configurations were generated to be responsive to these guidelines. Biomedical and biological COLs for which layouts were drawn are summarized in the lower part of Table 3-2. The upper part shows optional design parameters and the various FPEs considered for those layouts and the numbering system used to identify the options used in each layout. The first FPE column lists the FPEs according to an assigned code number. For example, the number 1.3 would designate a concept intended to support the cells and tissues FPE.

The second column indicates the optional ways in which the COLs could achieve isolation of the organisms from the crew during organism handling procedures. Isolation could be obtained by a transparent, flexible, plastic cover placed over the organism holding unit to form a seal and yet provide access to the organisms by the crew. Access could be provided by arm slots in the cover (Option 2.2) or by gloves integral with the cover (Option 2.1). The latter option provides less chance of cross-contamination than the arm slots, but the gloves are more difficult and time-consuming to use. A third option would be to eliminate any partition and have an open system (Option 2.3).

Table 3-2. Biomedicine and Biology Layout Parameter Options and Concepts Considered

	1.0 FPE	2.0 ISOLATION	3.0 ECS	4.0 MODULE CONFIGURATION	5.0 CREW INTERFACE	6.0 CAGE UNIT SIZE
Possible Options	1.1 Biomedicine 1.2 Vertebrates 1.3 Cells & Tissues 1.4 Invertebrates 1.5. Plants	2.1 Soft Glove Box 2.2 Arm Slots 2.3 Open	3.1 Open 3.2 Closed 3.3 None	4.1 Standard (.61×.61 m) 4.2 Custom	5.1 Standing 5.2 Seated	6.1 CVT* 6.2 Custom

Sets of Options for Which COL Lay-outs Were Drawn

LAYOUT DESIGNATION, Fig. #	1.0	2.0	3.0	4.0	5.0	6.0
Biomed/Biology Common Lab						
C-1, Fig. 3-2	All	2.1	3.2	4.2	5.2	6.1
C-2, Fig. 3-3	1.2	2.1	3.2	4.2	5.2	6.1
C-3, Fig. 3-4	1.1	2.3	3.3	4.2	5.2	NA
Biomedicine						
B-1, Fig. 3-5	1.1	2.3	3.3	4.2	5.2	NA
B-2, Fig. 3-6	1.1	2.3	3.3	4.1	5.1	NA
Biology						
F-1, Fig. 3-7	1.2	2.2	3.2	4.2	5.2	6.1
F-2, Fig. 3-8	1.2	2.2	3.1	4.2	5.2	6.1
F-3, Fig. 3-9	1.2	2.3	3.2	4.1	5.1	6.1
F-4, Fig. 3-10	1.4	2.2	3.2	4.2	5.2	6.2
F-5, Fig. 3-11	1.3	2.1	3.2	4.2	5.2	6.2
F-6, Fig. 3-12	1.5	2.3	3.2	4.2	5.2	6.2

*"BEST" cage size increased as a result of CVT/ARC recommendation.
"BEST" exterior cage dimensions ≈ $6\frac{1}{2}$"W × 8" H × 13" L - CVT*≈ 9" W × 10" H × 13" L.

The third column, designated ECS, refers to the type of organism ECS assumed for each layout. It lists three options of open, closed, or none. (None refers only to biomedicine COLs that contain no organisms.) The open type of organism ECS uses air from the crew compartment for the organism and then exhausts this air back into the crew compartment or into the crew ECS. The closed system, however, contains its own air revitalization equipment, and the organism air does not mix with cabin air.

The fourth and fifth columns indicate options on the overall COL configuration and the way in which the crewmen would address the COL. Option 4.1 refers to the placement of the COL equipment in a standardized rack or console-shaped structure about 0.61 m wide by 0.61 m deep, and a height compatible with the individual FPE requirements. The optional configuration (4.2) was entirely custom shaped to the individual FPE, except that the shapes used had to fit through a 102-cm (40-inch) -diameter hatch. Option 5.1 refers to layouts in which the crew would address the COL in a standing position, whereas with Option 5.2 he would be seated.

Column six contains two options regarding the size of holding units used for the organisms. Option 6.1 refers to the use of a standard size independent of the individual FPE needs but based on an across-the-board evaluation of the requirements of all biology FPEs. This standard holding unit size was based on the cage module used in the concept verification testing at NASA/MSFC, and will accommodate six to eight rat cages, depending on their size. The optional COL configuration (6.2) contained custom-sized holding units. For the cells and tissues FPE, for example, the holding unit was reduced in size since the full concept verification test (CVT) size did not appear warranted.

Certain combinations of the layout options were selected for use in generating conceptual COL layouts. These combinations are tabulated in the lower portion of Table 3-2, and the corresponding layout drawings are presented in Figure 3-1 through 3-11 at the end of Section 3.2. The eleven selected concepts are further divided into three groups, as shown in Table 3-2. The first group is that for a common COL specifically configured for the support of both biomedicine and the biology FPEs. The second grouping includes two COL layouts devoted primarily to biomedicine but capable of limited support for certain biology FPEs. The third group includes three concepts specifically for small vertebrates and one concept each for invertebrates, cells and tissues, and plants. Each layout concept is discussed individually in the following paragraphs.

3.2.1 SPECIFIC BIOMEDICINE AND BIOLOGY LAYOUT CONCEPTS

3.2.1.1 Biomedicine/Biology Common COL — Concept C_1, Biology Research Missions. The common laboratory design concept includes a specimen preparation, analysis, and storage console placed on the left side of the COL. (See Figure 3-1.) This console is designed such that it can be used alone with a biomedical FPE mission or in combination with an organism housing module and an environmental control system module (on the right) for any of the four biology FPEs. When used with one of the biology FPE missions, the design concept provides a flexible, transparent glove box option if control of cross-contamination is required. The glove box would be attached to enclose the front access surface of the organism housing unit and the adjacent attached specimen preparation, analysis, and storage console. In this manner, the experimental organisms and all media and equipment that contact them, or specimens collected from them, could be isolated from the experimenter and his environment in a closed environmental control system if required. The flexible glove box could also be used with an open ECS in which air from the crew environment could be used to ventilate the organism housing unit. In this latter case, the effluent air containing microbiological and organic waste matter, after passing through the organism housing unit and glove box, could be filtered prior to returning it to the crew environment. Equipment items are arranged such that if a closed environmental control system and strict experimental isolation were required, those equipment items that would not be contaminated during the experimental operations would be located outside the glove box area to facilitate free access for operation and maintenance. The glove box can be designed to provide a pass-through provision so items can be passed into or removed from the isolated area without loss of contamination control.

The portion of the specimen preparation, analysis, and storage console below the work bench can be separated from the upper glove box enclosed portion. This maintains the required cross-sections of the modules to allow passage through a 40-inch hatch. Freedom to increase one dimension of any module (that dimension not influencing the cross-sectional area) is provided by this concept. This allows upward adjustment of module volumes (e.g., kit storage space, animal cages, organism housing unit, etc.) if required during a final design effort without impacting the design concept.

The modules were configured for compatibility with normal one-g operations (controls) and for operation when attached to a longitudinal floor in a spacecraft. Access was assumed to be limited to outward-facing surfaces of the laboratory. The design accordingly can accommodate installation against walls, in corners, or enclosed by adjacent structures. Rectangular shapes were employed to provide interchangeability and to accommodate off-the-shelf equipment items. The preliminary estimates of weight and volume required for this design concept are shown in Figure 3-1.

The following two paragraphs describe this same COL configured to support vertebrate/man surrogate and biomedical research missions.

3.2.1.2 Biomedicine/Biology Common COL — Concept C_2, Vertebrate/Man Surrogate Mission. The vertebrate/man surrogate COL configuration was expected to require less equipment than the COL equippped to support the total vertebrate research requirement. Research such as crew cardiopulmonary system responses to the space environment that will be performed directly on man would not be performed on the man surrogates. Also, electrophysiological monitoring during these missions would probably be limited to ECG and body temperature to provide long-range status information on the subjects at minimal weight, volume, and power penalties to the supporting spacecraft. The research emphasis would be directed to invasive techniques (tissue biopsy) and other studies that would not be performed on human subjects. Vertebrate/man surrogate COL equipment must provide for housing and maintaining the animals, performing limited electrophysiological monitoring, and provide for maximum capability to collect, prepare, preserve, and transport tissues, body fluids, and waste products for delayed ground analyses. The COL for man surrogate research is shown in Figure 3-2. Even though it contains slightly less equipment and therefore weighs less, its layout configuration is practically identical to the vertebrate research COL, concept C_1.

3.2.1.3 Biomedicine/Biology Common COL — Concept C_3, Biomedical Research Mission. The specimen preparation, analysis, and storage console used for the biology research missions described in the previous paragraphs is also used for the biomedical research mission (Figure 3-3). The glove box, organism housing module, and environmental control system module are not required for the biomedical FPE. Space is provided for couplers selected for biomedical data management. The concept would allow interface with experiment-specific equipment items and related research operations such as lower body negative pressure, rotating litter chair, and primate experiments. The specimen preparation, analysis, and storage console would be equipped with biomedical kits located within the storage volume provided. This concept, as configured, provides the capability to prepare and store biological fluids collected from the crew for limited onboard or comprehensive delayed ground analysis, as required.

3.2.1.4 Biomedicine COL — Concept B_1. This configuration shown in Figure 3-4, is primarily devoted to biomedicine. However, it contains an enclosed space identified as Space for Special Equipment or Organism Housing Unit. Thus, the concept could possibly be used to support certain biological FPEs as well as the biomedical missions. The leg space provided in this configuration places an excessive volume demand on the laboratory. The laboratory is configured to accommodate research operations by a seated experimenter.

3.2.1.5 Biomedicine COL — Concept B_2. This concept, Figure 3-5, adopts the desired commonality feature of Concept B_1, but the space provided for special medical equipment or organism housing unit was relocated. The revised location, on the side of the module rather than enclosed within other laboratory structures as in B_1, provides flexibility to the concept by being compatible with a wide range of organism housing unit sizes and volumes. This concept avoids the excess use of leg space volume that was apparent in the B_1 concept. A collapsible shelf is provided to facilitate reducing the dimension of the module to enable passage through spacecraft hatches. A disadvantage of concept B_2 is the increased height created in this packaging concept and the attendant requirement for experimenter operations in a standing position.

3.2.1.6 Biology COL — Concept F_1. This concept, Figure 3-6, is configured for the vertebrate research mission, and provides a glove box for isolation. It initiates a design feature of access doors through the work bench to increase the volume that can be used while operating within the glove box isolation. This concept also provides access to a side panel surface and increases work bench surface area realtive to that provided by other options. The configuration places an excessive demand on experimenter leg space volume.

3.2.1.7 Biology COL — Concept F_2. This vertebrate COL concept, Figure 3-7, is identical to Concept F_1 except it omits the glove box isolation mode of operation. It uses an open ECS and is slightly lighter than Concept F_1.

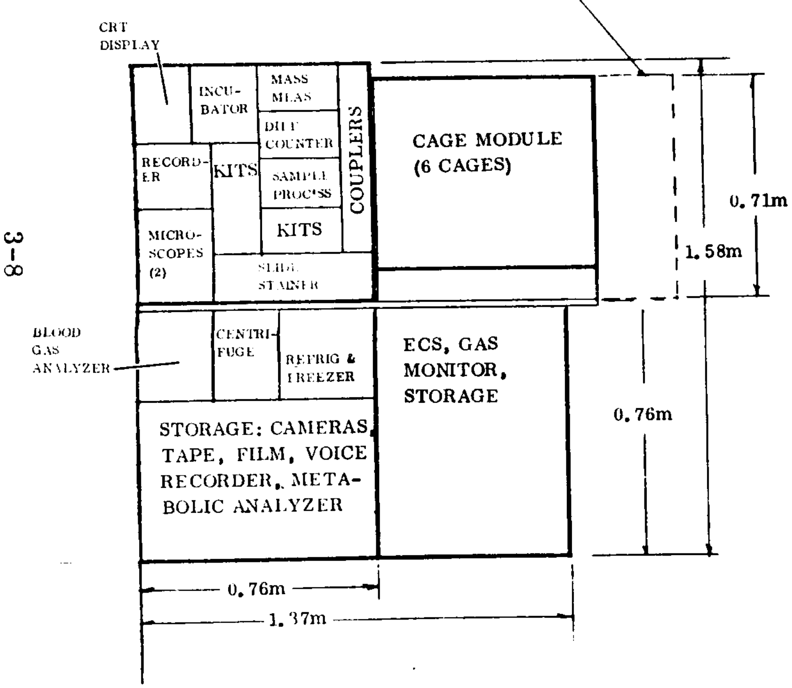
3.2.1.8 Biology COL — Concept F_3. This configuration, Figure 3-8, is also for vertebrate research and avoids the wasted volume for leg room present in the previous concepts, although this makes it difficult to accommodate seated operations. It provides an uncluttered work surface to accommodate a wide range of experiment-specific equipment sizes and shapes. One weakness is the lack of a mechanism to prevent contaminants from being dislodged from the open work surface.

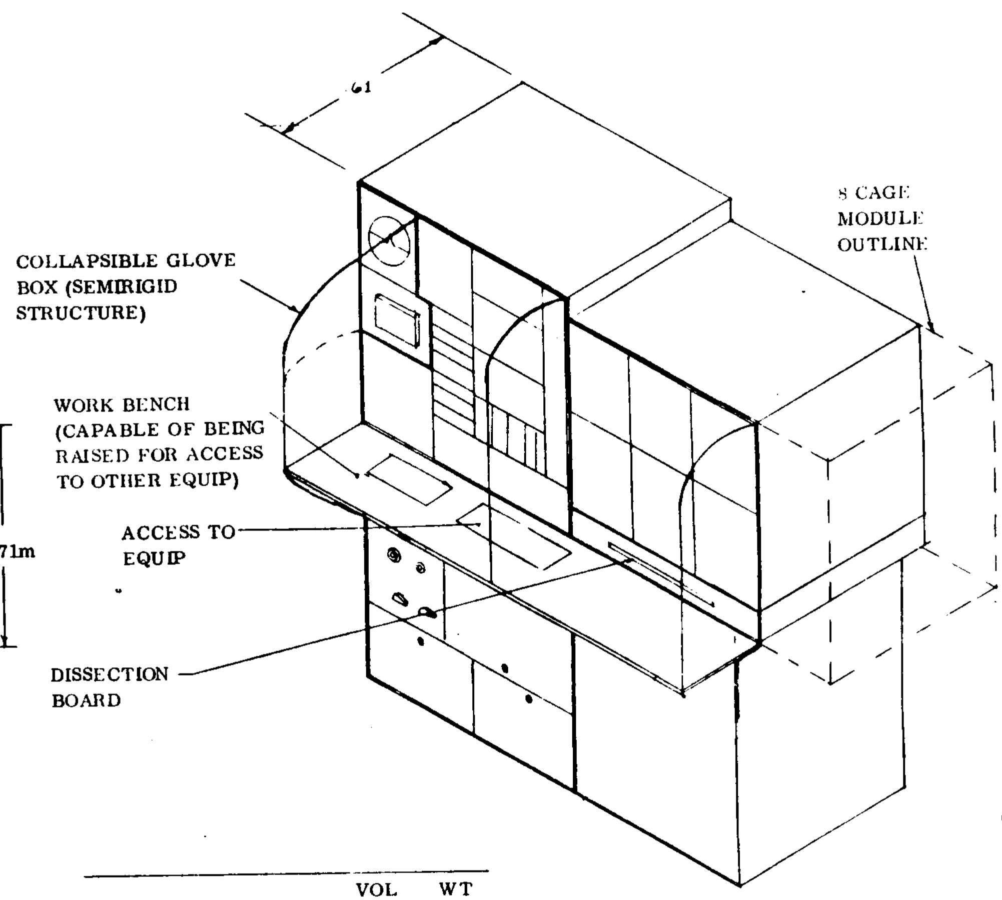
3.2.1.9 Biology COL — Concept F_4. This configuration accommodates the invertebrate carry-on mission and is shown in Figure 3-9. It is similar to Concept F_1 for vertebrate missions to provide significant potential for the use of common equipment. It demonstrates an isolation mode using arm slots rather than integrated gloves. In other respects, it has the same advantages and disadvantages of Concept F_1.

3.2.1.10 Biology COL — Concept F_5. This configuration for cells and tissues research also employs the general concept employed in Concepts F_1 and F_4, and is shown in Figure 3-10.

3.2.1.11 Biology COL — Concept F_6. This concept, Figure 3-11, satisfies the plant research requirements. Design characteristics emphasized in this alternative are the increased work bench surface area and increased accessible module surface area. Considerable volume is wasted in the leg space provided by this configuration. The commonality potential of this configuration is less than for the previous examples.

3.2.2 RECOMMENDED BIOMEDICINE AND BIOLOGY COL LAYOUT CONCEPTS. It was apparent from the layout studies that the vertebrate research COLs required greater weight, volume, and power than the other FPEs. Accordingly, this FPE was recommended for the baseline design. It appeared that a common design based on vertebrate requirements would encompass all requirements of the biomedical and other biology research missions. The design concept that corresponds to this recommendation is the Biomedicine/Biology Common Laboratory. This was shown in Figures 3-1 through 3-3.





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	1031	288
GPRE MODULE	1322	53
EXP SPECIFIC EQUIP	—	—
TOTAL ENVELOPE	1700	341

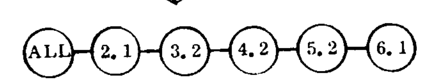
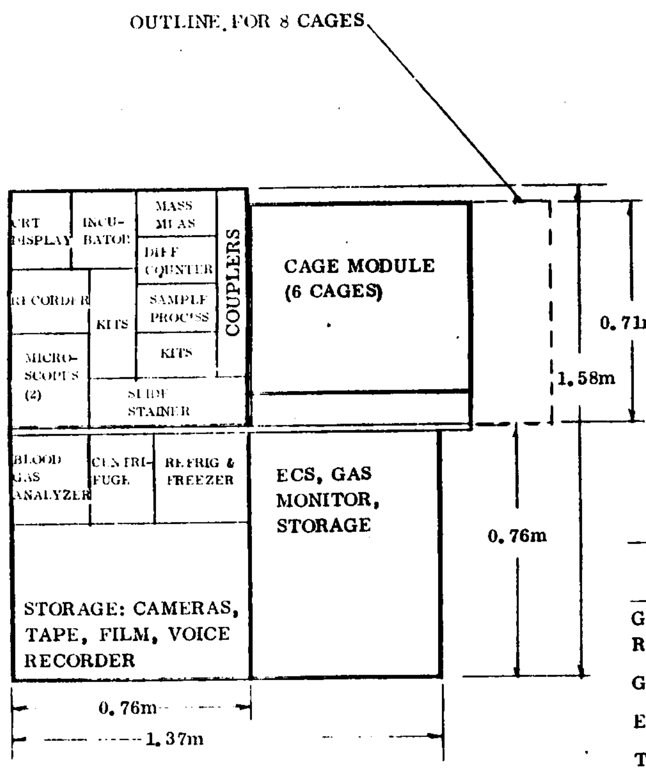
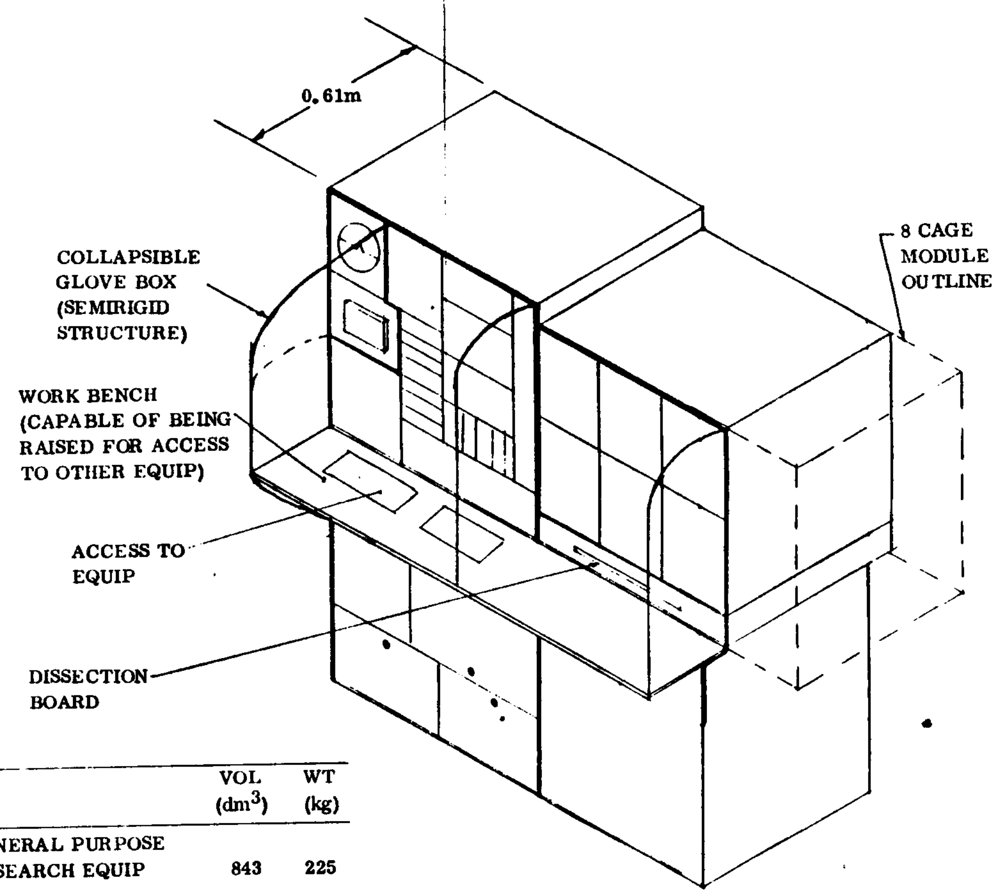


Figure 3-1. Biomedicine and Biology Combined COL — Concept C_1, Vertebrate Research Mission

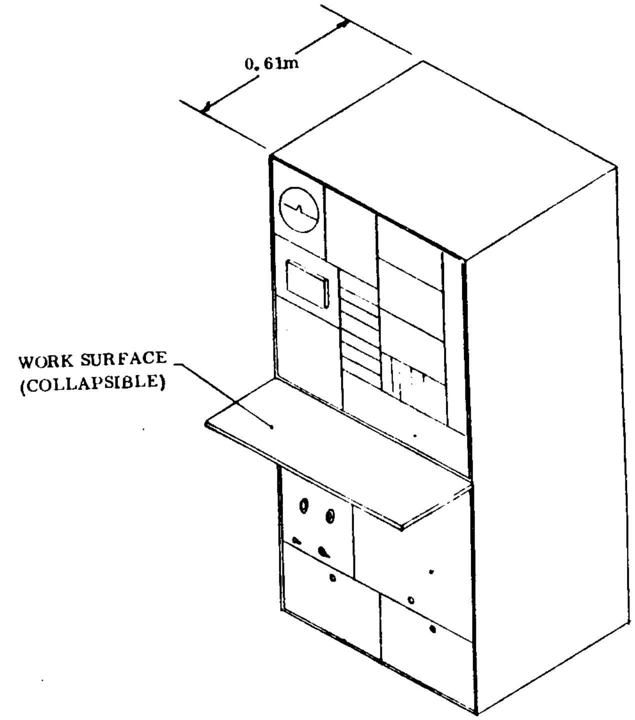


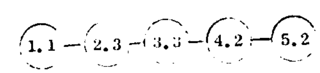


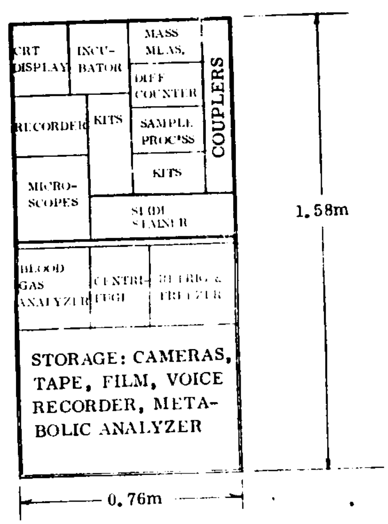
	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	843	225
GPRE MODULE	1322	53
EXP SPECIFIC EQUIP	—	—
TOTAL ENVELOPE	1700	278

1.2 — 2.1 — 3.2 — 4.2 — 5.2 — 6.1

Figure 3-2. Biomedicine and Biology Combined COL — Concept C_2, Vertebrate Man-Surrogate Mission

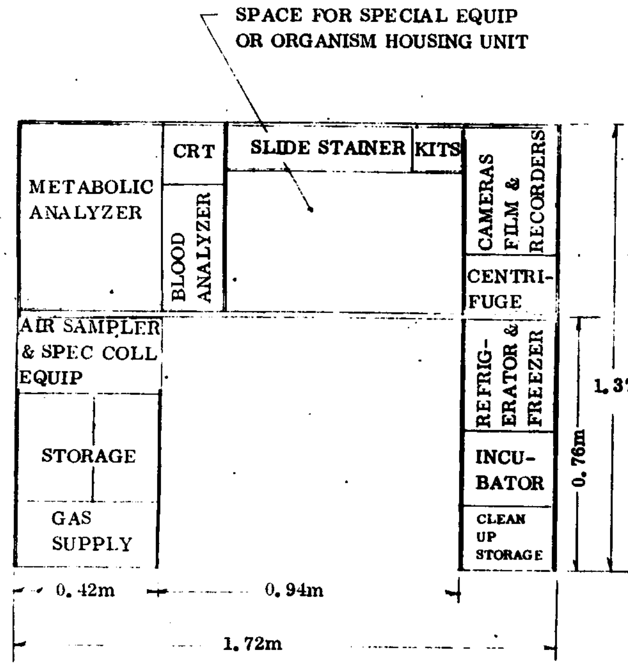


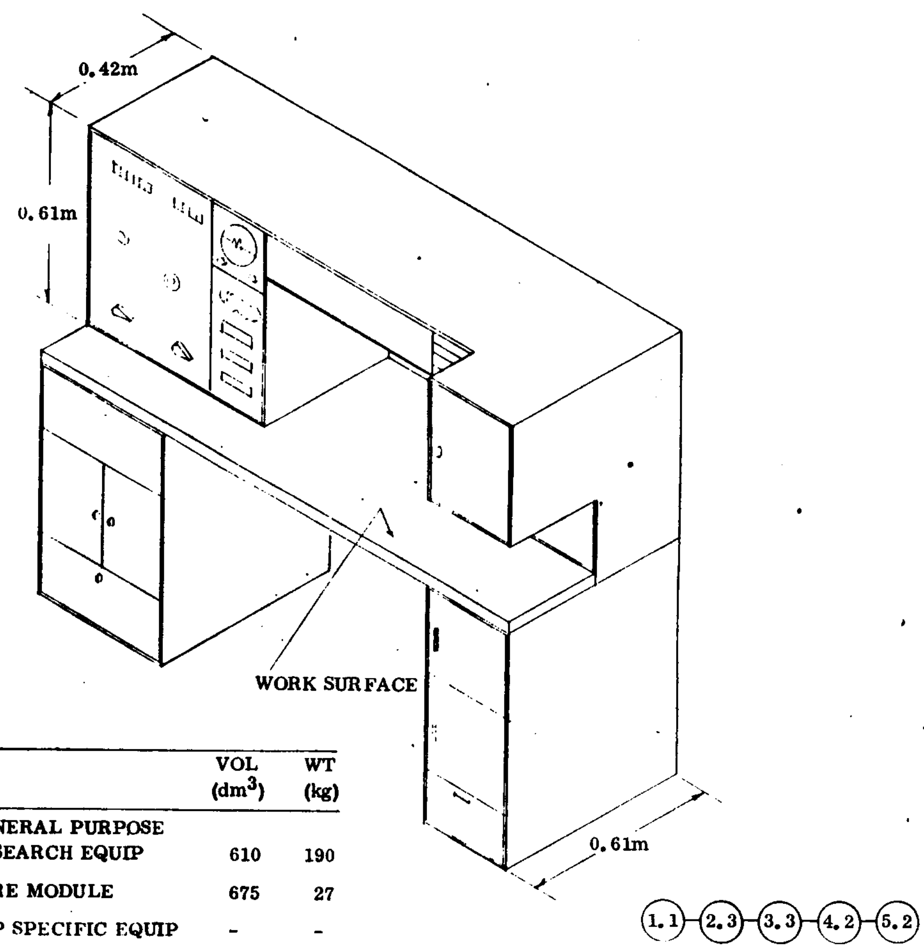




	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	610	190
GPRE MODULE	730	29
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	730	219

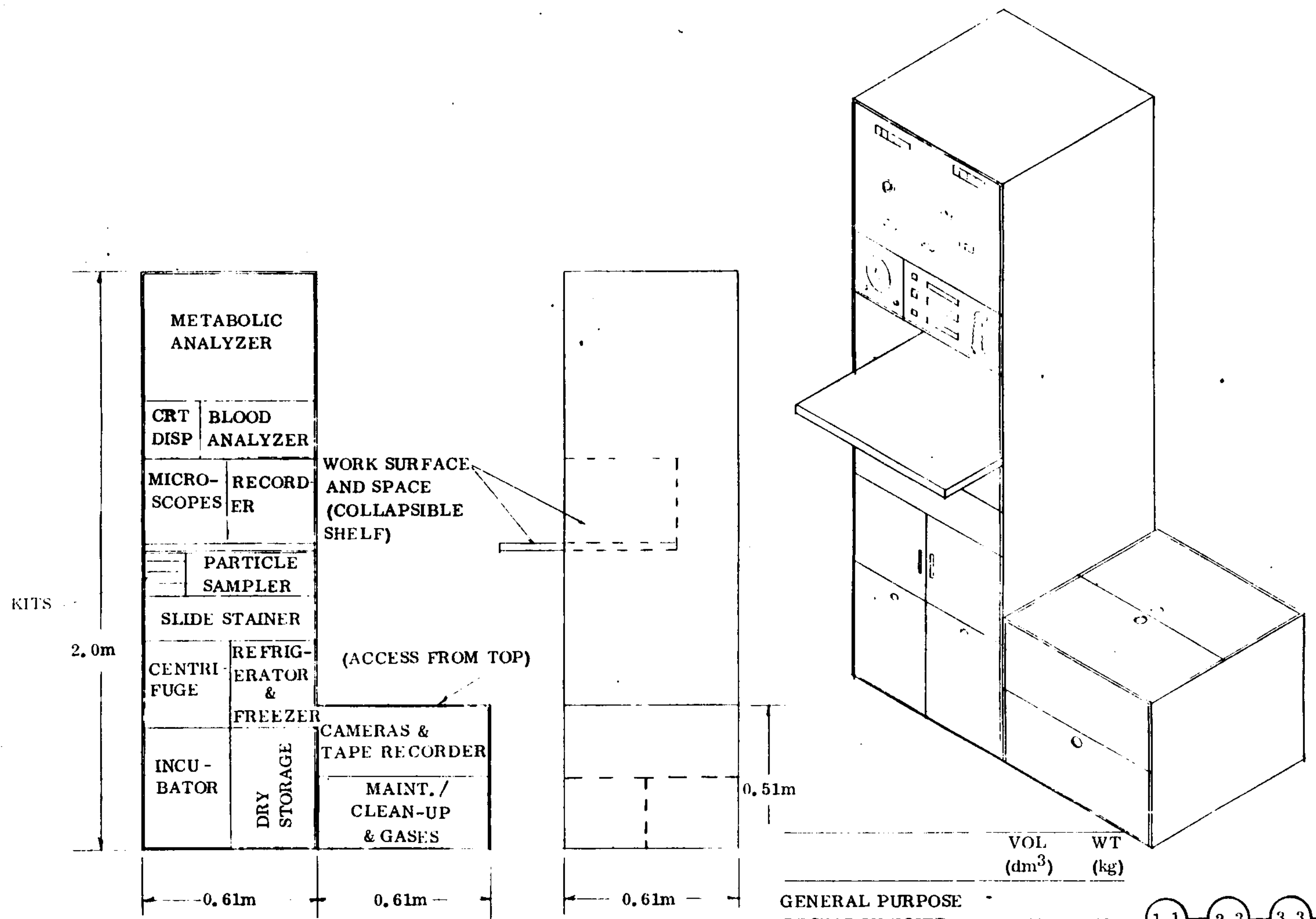
Figure 3-3. Biomedicine and Biology Combined COL — Concept C_3, Biomedical Research Mission





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	610	190
GPRE MODULE	675	27
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	1240	217

Figure 3-4. Biomedicine COL — Concept B_1



	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	610	190
GPRE MODULE	935	37
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	935	227

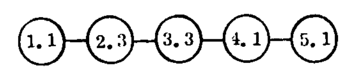
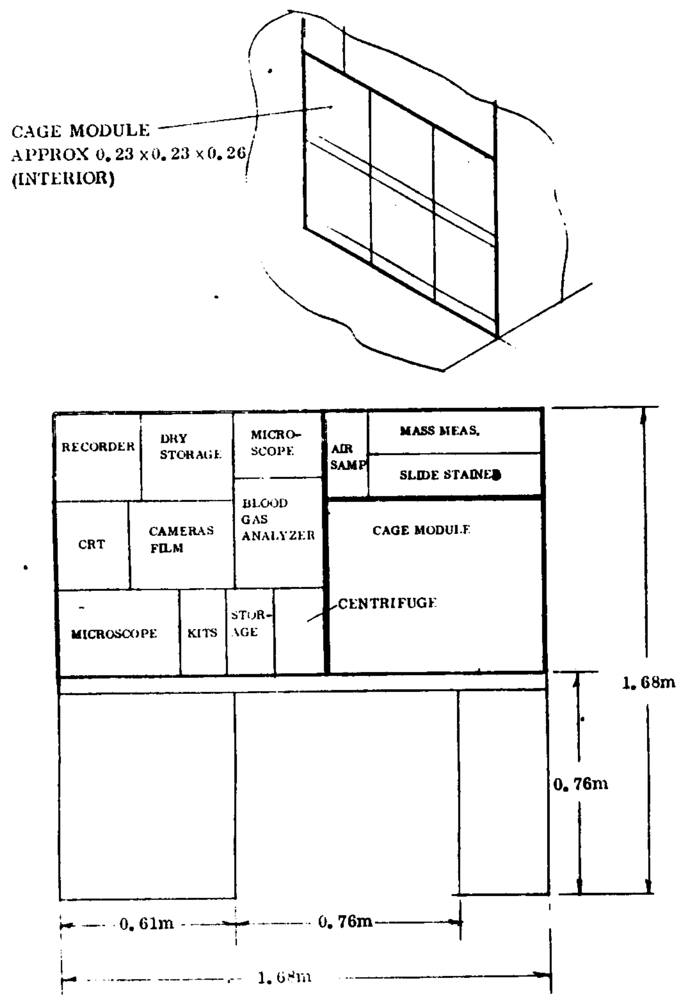
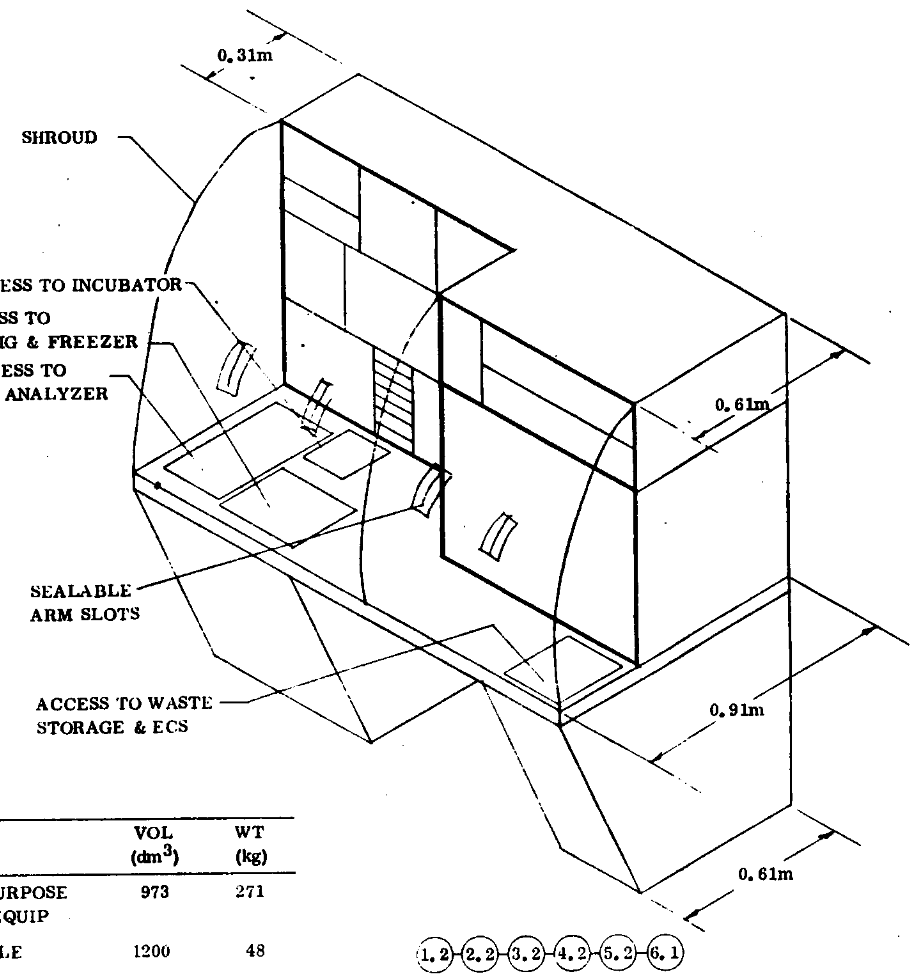


Figure 3-5. Biomedicine COL — Concept B_2

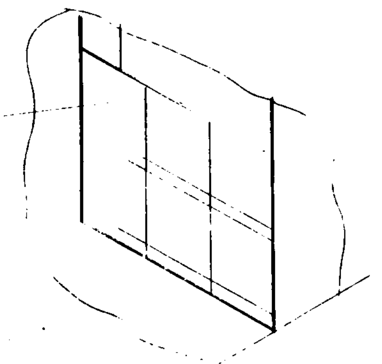


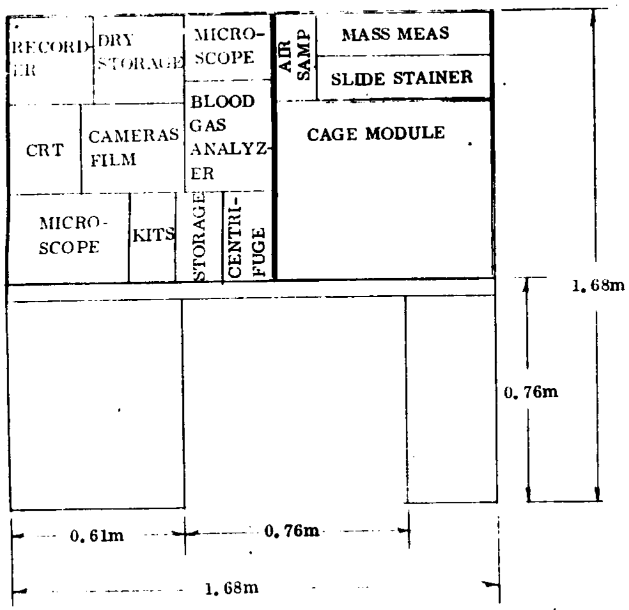


	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	973	271
GPRE MODULE	1200	48
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	2560	319

Figure 3-6. Biology COL — Concept F_1, Vertebrate Research

CAGE MODULE
APPROX 0.23 x 0.23 x 0.26
(INTERIOR)



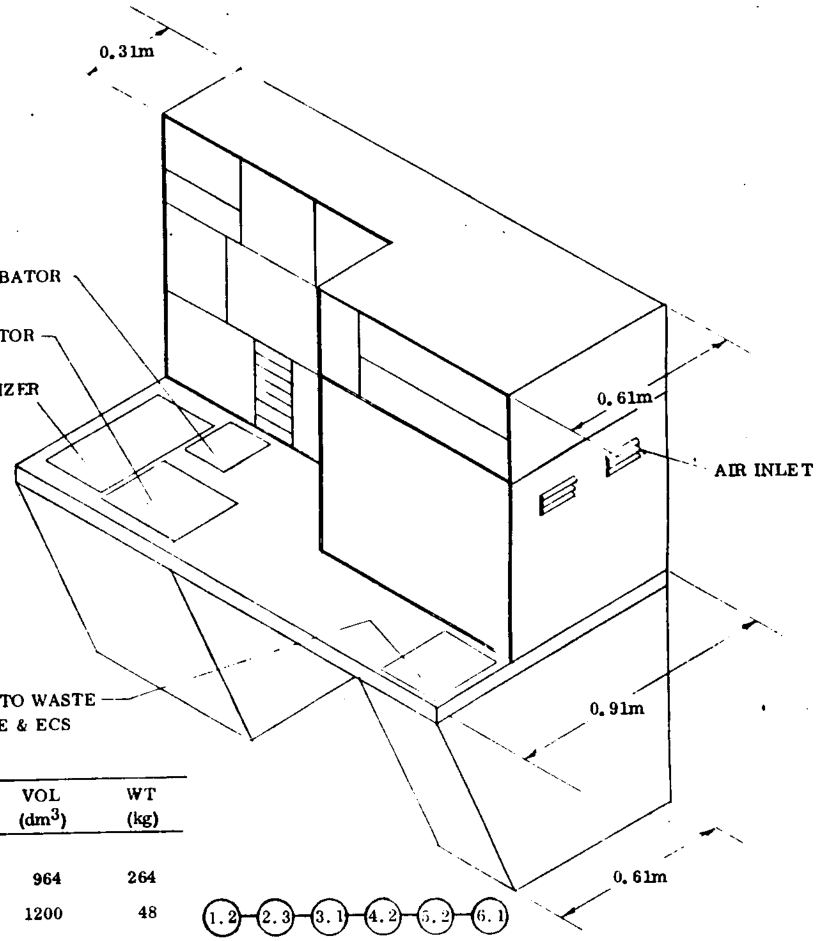


ACCESS TO INCUBATOR

ACCESS TO REFRIGERATOR & FREEZER

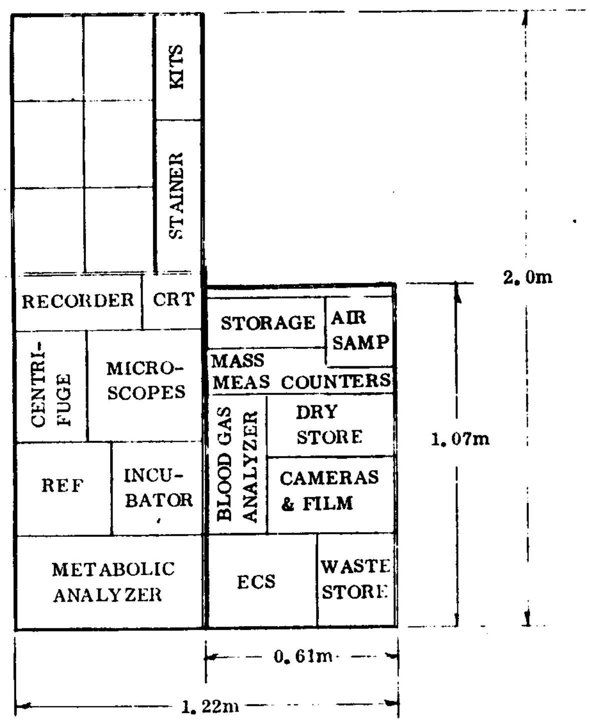
ACCESS TO GAS ANALIZER

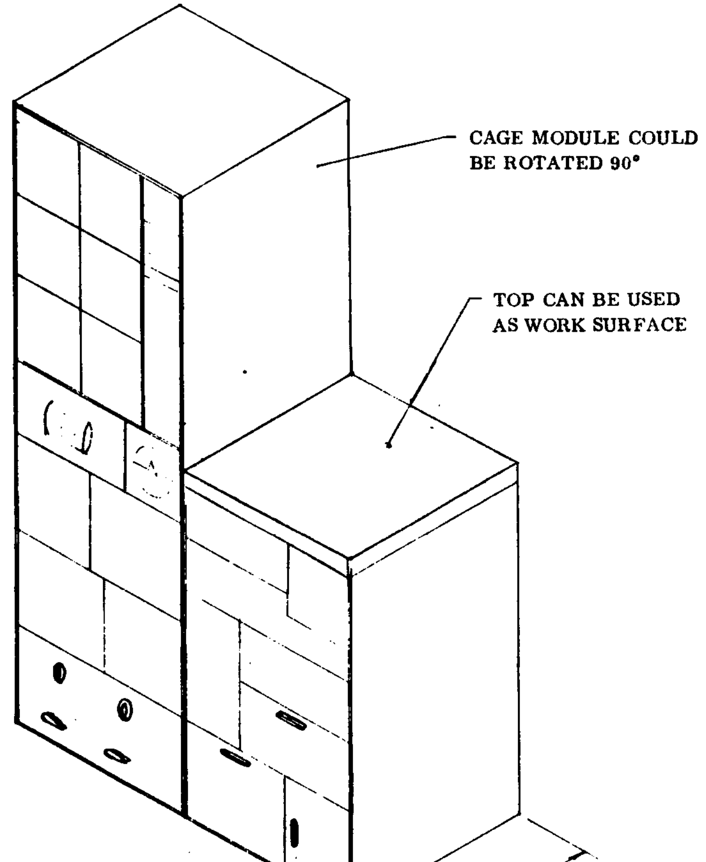
ACCESS TO WASTE STORAGE & ECS

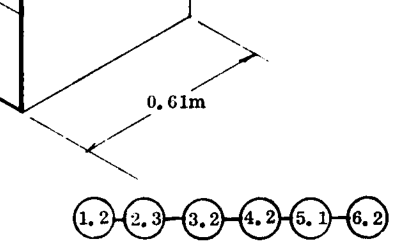


	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	964	264
GPRE MODULE	1200	48
EXP SPECIFIC EQUIP	–	–
TOTAL ENVELOPE	2560	312

Figure 3-7. Biology COL — Concept F_2, Vertebrate Research

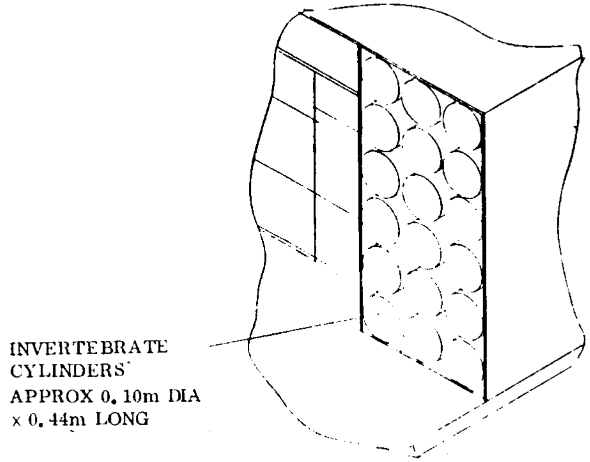


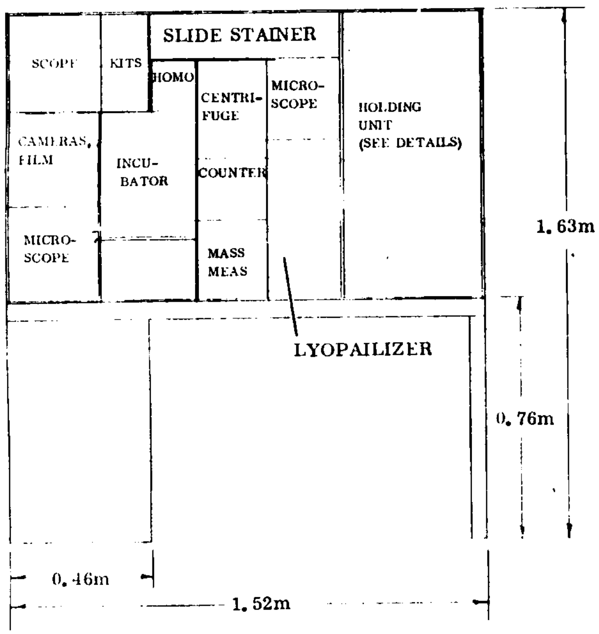


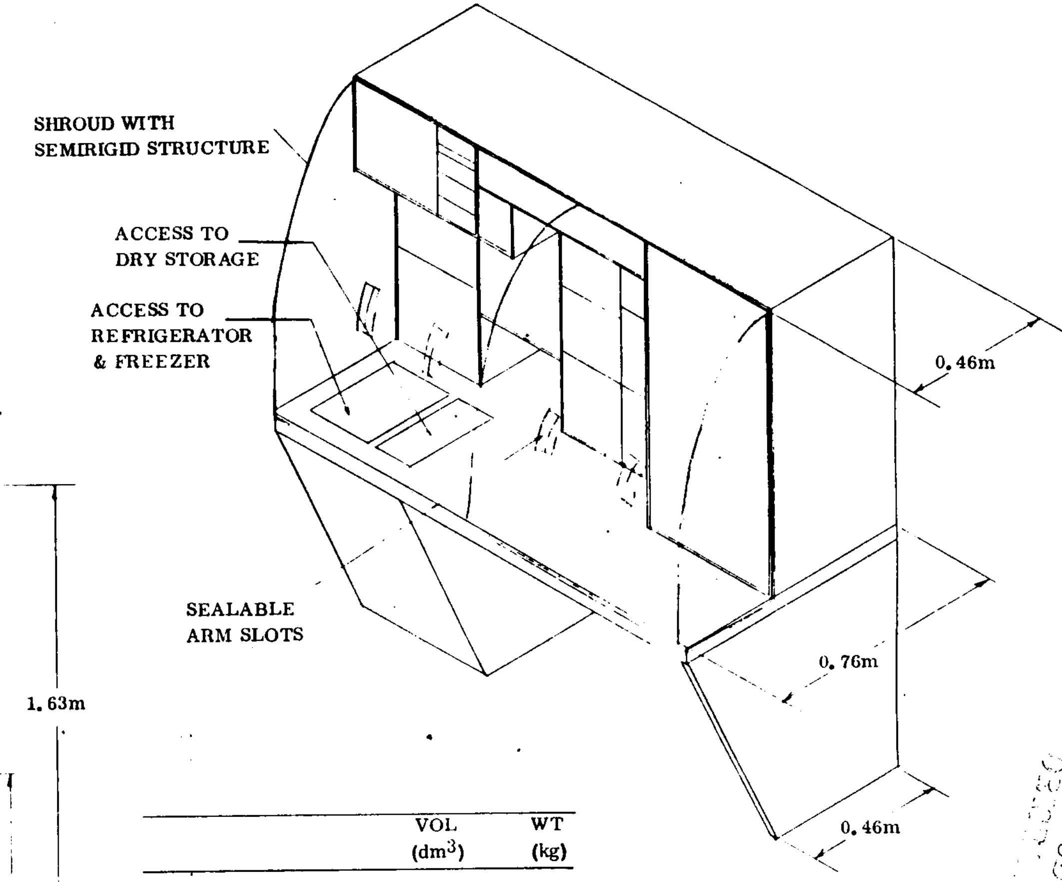


	VOL (dm³)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	973	271
GPRE MODULE	1145	46
EXP SPECIFIC EQUIP	–	–
TOTAL ENVELOPE	1145	317

Figure 3-8. Biology COL — Concept F_3, Vertebrate Research



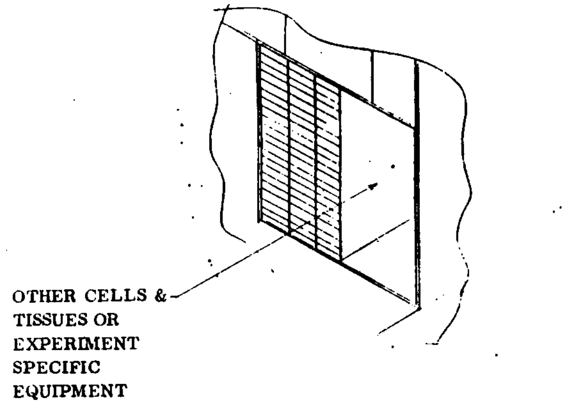


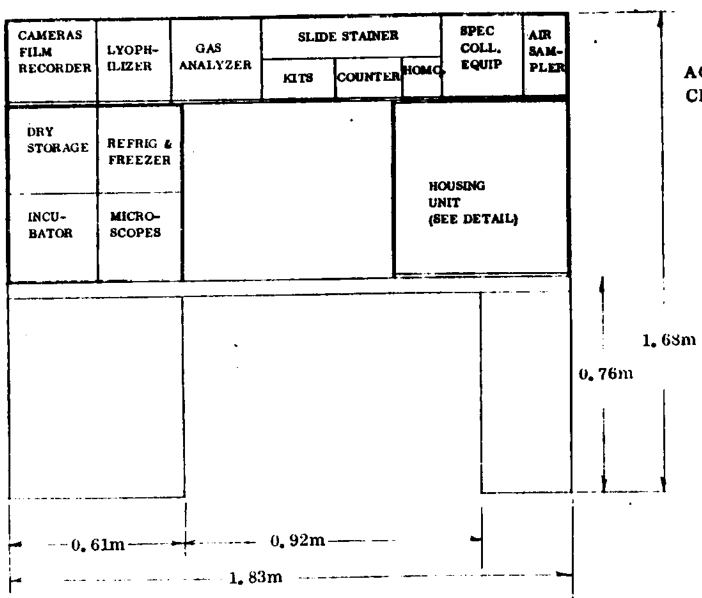


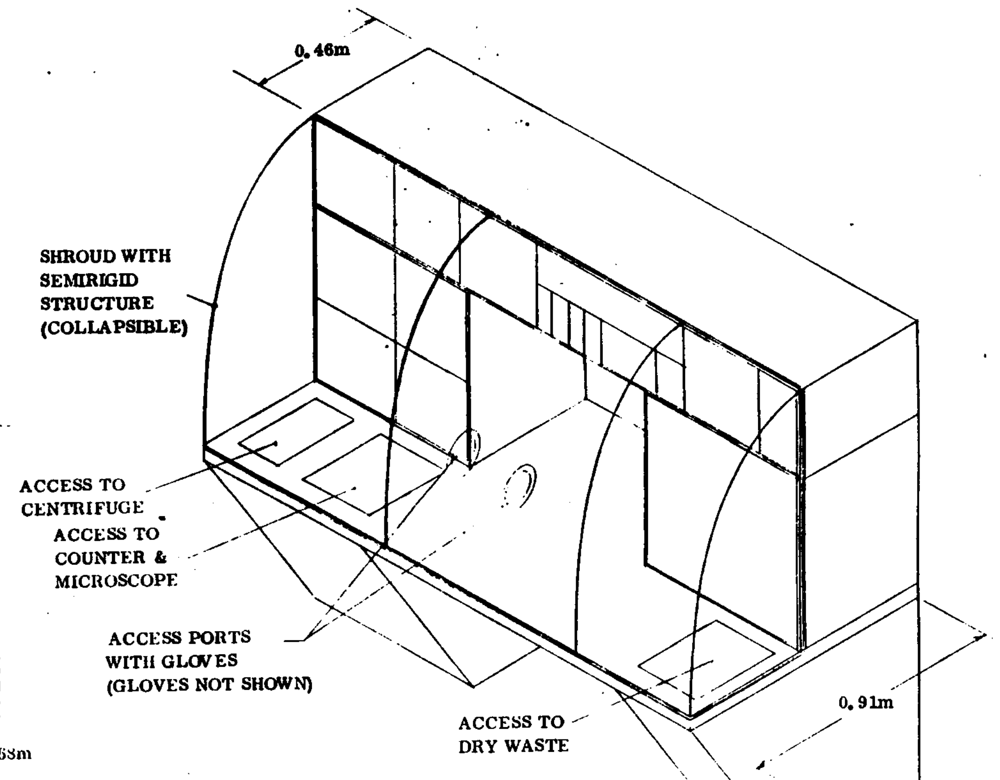
	VOL (dm³)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	722	172
GPRE MODULE	771	31
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	1390	203

1.4 – 2.2 – 3.2 – 4.2 – 5.2 – 6.2

Figure 3-9. Biology COL — Concept F_4, Invertebrate Research







	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	673	166
GPRE MODULE	930	37
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	2800	203

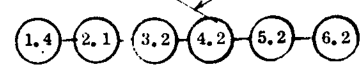
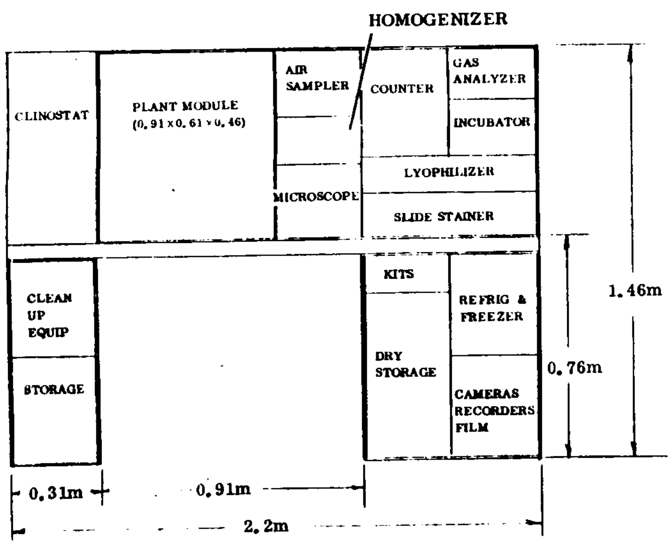
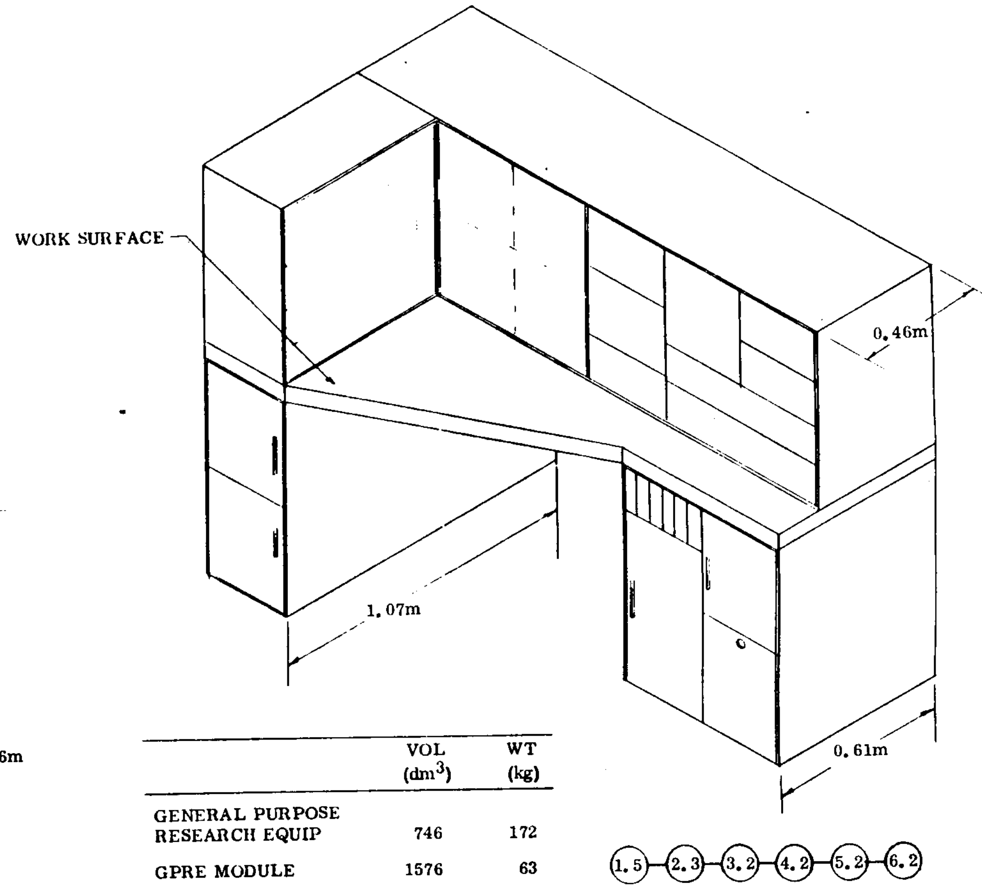


Figure 3-10. Biology COL — Concept F_5, Cells and Tissues Research





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	746	172
GPRE MODULE	1576	63
EXP SPECIFIC EQUIP	–	–
TOTAL ENVELOPE	2168	235

Figure 3-11. Biology COL — Concept F_6, Plant Research

3.3 MAN/SYSTEMS INTEGRATION COL LAYOUTS

This section describes several potential equipment layouts for a COL that would support a variety of experimentation in the man/systems integration (MSI) FPE. Table 3-3 presents the layout parameter options considered and the selected options used to guide development of the layouts. The meaning of the options regarding module configuration and crew interface was discussed in Section 3.2.

Seven combinations of equipment are proposed to support, in varying degrees, the high-priority experiments in MSI. These combinations were selected as best satisfying the criteria of maximum scientific return per pound of laboratory, having a high probability for ultimate development as a COL, and/or meeting specific NASA requests.

Each of the seven layouts is discussed below. The equipment groups and experiments referred to correspond to those presented previously in Section 2.2. For the reader's reference, the list of experiments in order of their importance are repeated below.

1. Effects of the Space Flight Environment on the Sensory Processes*
2. Effects of the Space Flight Environment on the Psychomotor Functions*
3. Cargo Handling Capabilities
4. Assembly, Deployment, Maintenance, and Repair Capabilities
5. Attached Teleoperator Manual Controllability
6. Free Flying Teleoperator Remote Controllability
7. Effects of the Spaceflight Environment on Individual and Group Dynamics
8. Locomotion and Restraint Capabilities
9. Effectiveness of End Effector Designs
10. Off-Duty Activity and Facilities
11. Evaluation of Miniature Accelerometers as Motion Sensors to Assess the Effect of Stress and Fatigue
12. Urine and Feces Collection, Measurement, and Sampling System
13. Inflight Determination of Bone Mineral Content
14. Compact Respiratory Measurement Systems
15. Automated Clinical Chemical Analyzer
16. System to Preserve Biological Materials

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*As noted in Section 2.2, these two experiments were de-emphasized because of a reassessment with respect to Skylab results.

Table 3-3. MSI COL Layout Parameter Options and Concepts Considered

POSSIBLE OPTIONS

1.0 EQUIPMENT GROUP COMBINATIONS	2.0 MODULE CONFIGURATION	3.0 CREW INTERFACE
1.1 †BME + DME	2.1 Standard Rack (.61×.61 m) cross-section	3.1 Standing
1.2 †BME + DME + AVME		
1.3 †AVME		3.2 Seated
1.4 †AVME + PME + ESE	2.2 Custom Shape	
1.5 †AVME + ESE		
1.6 AVME (partial) + PME + ESE		
1.7 AVME (partial) + ESE		
1.8 AVME (partial) + PME (partial) + ESE		
1.9 †AVME + PME (partial) + ESE		
1.10 BME (partial)		
1.11 BME (partial) + DME		
1.12 BME (partial + AVME		
1.13 BME (partial) + DME + AVME		
1.14 AVME + PME (partial)		

SELECTED OPTIONS †

COL LAYOUT DESIGNATION	EQUIPMENT COMBINATIONS	MODULE CONFIGURATION	CREW INTERFACE
H-1, Fig. 3-14	1.4	2.2	3.1
H-2, Fig. 3-15	1.9	2.2	3.2
H-3, Fig. 3-16	1.5	2.2	3.1
H-4, Fig. 3-17	1.2	2.2	3.2
H-5, Fig. 3-18	1.2	2.1	3.1
H-6, Fig. 3-19	1.3	2.1	3.1
H-7, Fig. 3-20	1.1	2.1	3.1

*BME - Behavioral Measurements Equipment
DME - Data Management Equipment
AVME - Audio-Visual Measurements Equipment
PME - Physiological Measurements Equipment
ESE = Experiment Specific Equipment

17. Medical Aspirator

18. Intravenous Fluid Administration Device

19. Blood Cell Counter

3.3.1 SPECIFIC MSI LAYOUT CONCEPTS

3.3.1.1 MSI COL — Concept H_1, Performance Measurements Laboratory. This concept, Figure 3-12, combines the following groups of equipment: 1) audio-visual measurements equipment (AVME), 2) physiological measurements equipment (PME), and 3) experiment-specific equipment (ESE). AVME provides for acquisition of visual records that are the source of the basic measurements such as task times, errors, etc. This equipment also provides for recroding real-time subject comments on experiment events, and non-interference auditory comments of the subjects during behavior studies. Immediate post-experiment subjective comments and critiques from experiment observers as well as test subjects may also be obtained. Thus, the auditory capability is applicable to all experiments. The PME provides a physiological measurement capability for heart rate monitoring, energy expenditure comparisons, etc., which is most useful on the non-behavioral measurement experiments (all excepts numbers 1, 2, 7, and 10). To allow subject movement over a considerable distance, this laboratory would require a metabolic gas analyzer such as a miniaturized backpack analyzer. The alternative, long gas lines used with the stripped-down Skylab metabolic analyzer shown, may compromise the measurement capability. The ESE provides the hardware being evaluated (a maintenance test bed, cargo-handling equipment, antenna sections for assembly and deployment, etc.). This would usually be required on all but a few experiments (1, 2, and 7). The outstanding feature of concept H_1 is its usefulness on almost all experimnets.

3.3.1.2 MSI COL — Concept H_2, Performance Measurements Laboratory (Metabolic Analyzer Deleted). The comments for Concept H_1 are applicable to H_2 except that the metabolic analyzer has been removed (Figure 3-13). Energy expenditure would be estimated by heart-rate correlations, thus freeing the test subject from encumbering hoses (or backpack should one be developed) but reducing accuracy of the data.

3.3.1.3 MSI COL — Concept H_3, Performance Measurements Laboratory (No Physiological Measurements). Concept H_2 comments apply, but with all physiological meas urement capability lost (Figure 3-14). This would still be a highly useful laboratory, however, as the physiological measurements will not be a primary measurement in most experiments.

3.3.1.4 MSI COL — Concept H_4, Behavioral Measurements Laboratory (Custom). This concept (Figure 3-15) combines the sensory and psychomotor measurement equipment (BME) from IMBLMS with the appropriate data management system interface equipment (DME) from IMBLMS and the audio-visual measurements equipment (AVME). Thus, BME and the DME provide the capability for sensory measurements (Experiment 1) and for psychomotor measurements (Experiment 2), while the AVME provides the capability for visual and auditory non-interference measurements necessary for Experiments 7 and 10. This custom design still maintains the proper juxtaposition of equipment to allow the test subject and/or experiment operator to function as required. Concept H_4 is primarily intended to support Experiments 1, 2, 7, and 10; however, the AVME would provide most of the basic measurement capability for any other experiment where an experiment-specific module is not required.

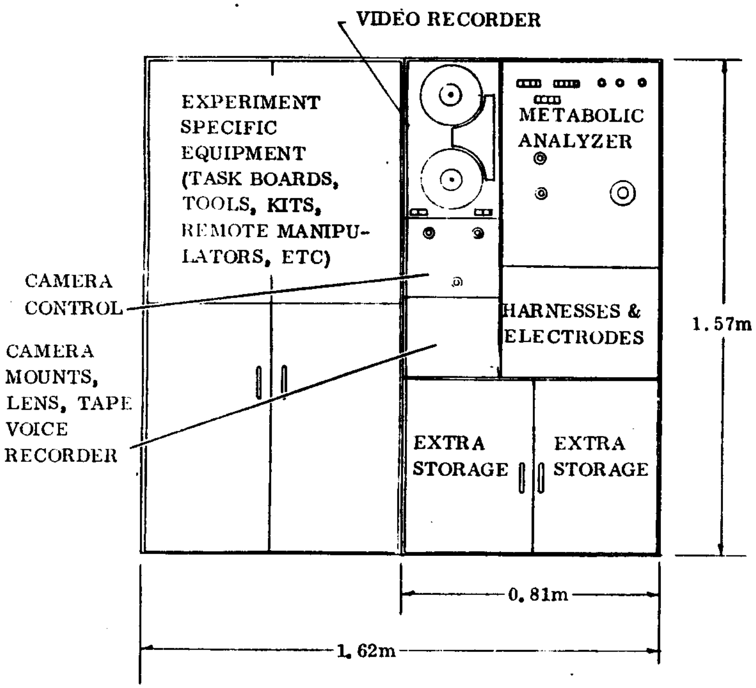
3.3.1.5 MSI COL — Concept H_5, Behavioral Measurements Laboratory (Standard). This layout is shown in Figure 3-16, and Concept H_4 comments apply. Concept H_5 has the advantage of standard packaging, but at the expense of test subject/operator inconvenience.

3.3.1.6 MSI COL — Concept H_6, Non-Interference Measurements Laboratory. This concept provides the audio-visual measurement capability only (Figure 3-17). It is compact and lightweight, and can be used to provide most required measurement capabilities for all but Experiments 1 and 2. Its primary limitation is that it can be used only for experiments that do not require experiment-specific equipment. It will be most useful for behavior studies and recording performance on operational (already existing) equipment and tasks.

3.3.1.7 MSI COL — Concept H_7, Laboratory for Experiments 1 and 2 Only. This concept (Figure 3-18) contains only sensory and psychomotor measurement equipment and its necessary data management interface equipment. It provides the measurement capability for Experiments 1 and 2 only. Experiment 3 would require both the AVME and the ESE, and the total package would far exceed tentative laboratory constraints. This concept would be most useful on long-duration missions.

3.3.2 RECOMMENDED MSI COL LAYOUT CONCEPTS. Concept H_2 was recommended for further development during the Task C conceptual design phase. It provides almost all of the measurement capability required for the majority (and the most probable) of the MSI experiments and lacks only the measurement capability provided by the metabolic analyzer. Since the analyzer is currently very large and encumbering to the test subject, its deletion is consistent with the goals of the COL concept.

As an alternative, concept H_6 was recommended. This COL would have wide application (although a more limited measurement capability) and would easily fall within the constraints of the COL, even with multiple camera requirements.



	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	340	92
GPRE MODULE	635	25
EXP SPECIFIC EQUIP	635	25 + ESE
TOTAL ENVELOPE	1370	142 + ESE

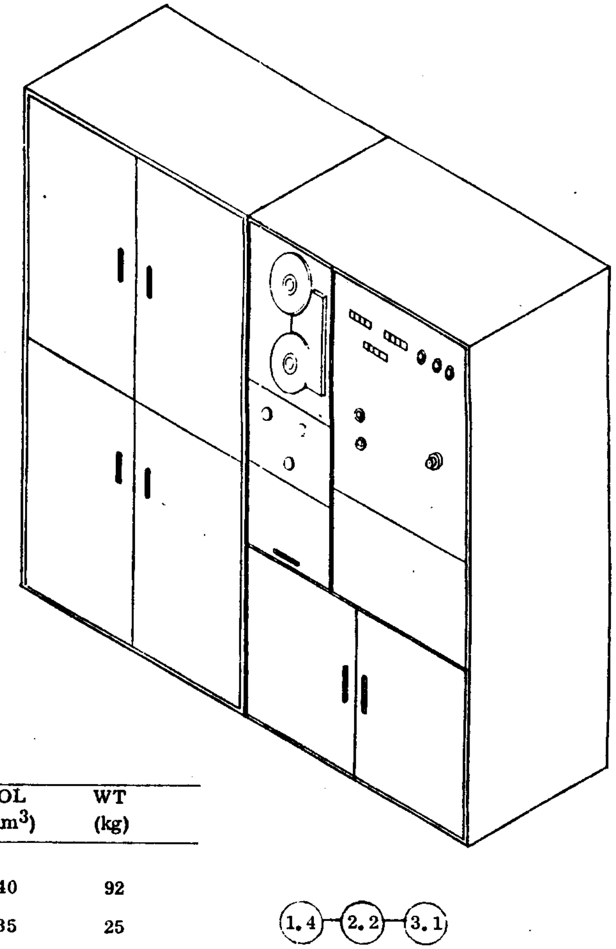
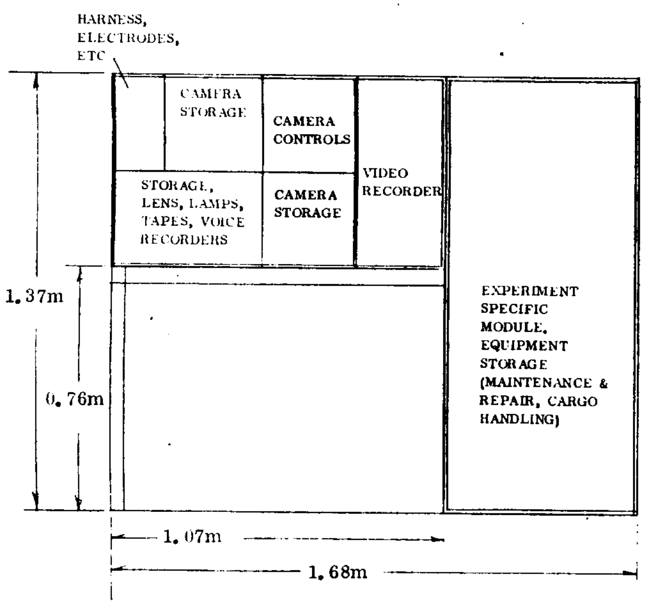
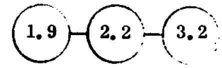


Figure 3-12. MSI COL — Concept H_1, Performance Measurements Laboratory

	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	198	69
GPRE MODULE	268	11
EXP SPECIFIC EQUIP	510	20 + ESE
TOTAL ENVELOPE	778	100 + ESE





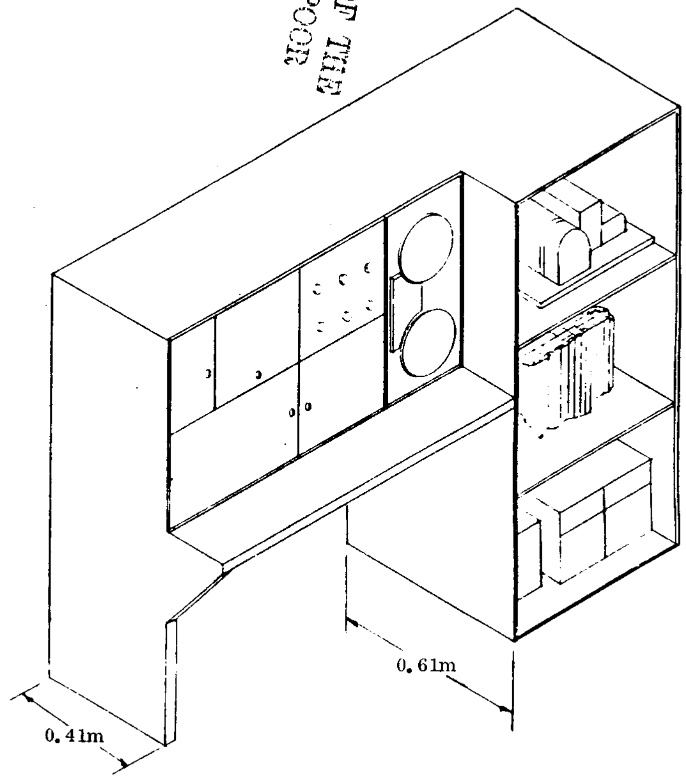


Figure 3-13. MSI COL — Concept H_2, Performance Measurements Laboratory (No Metabolic Analyzer)

	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	198	69
GPRE MODULE	210	9
EXP SPECIFIC EQUIP	530	21 + ESE
TOTAL ENVELOPE	740	99 + ESE

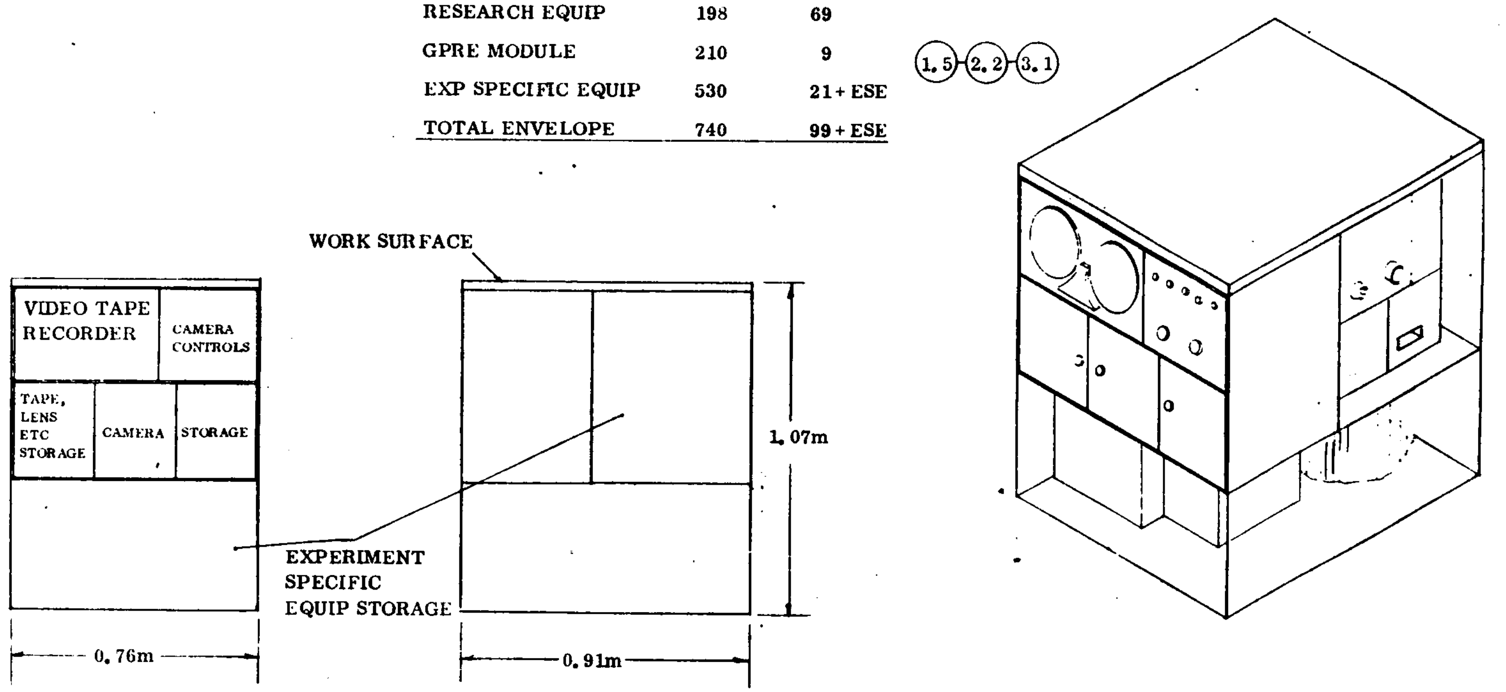
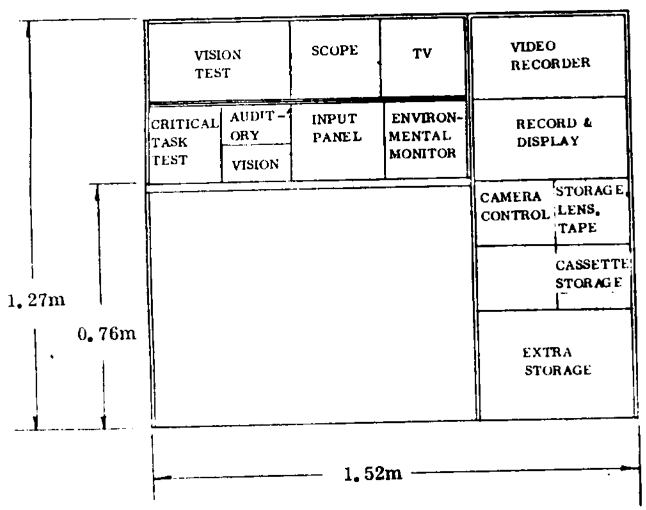
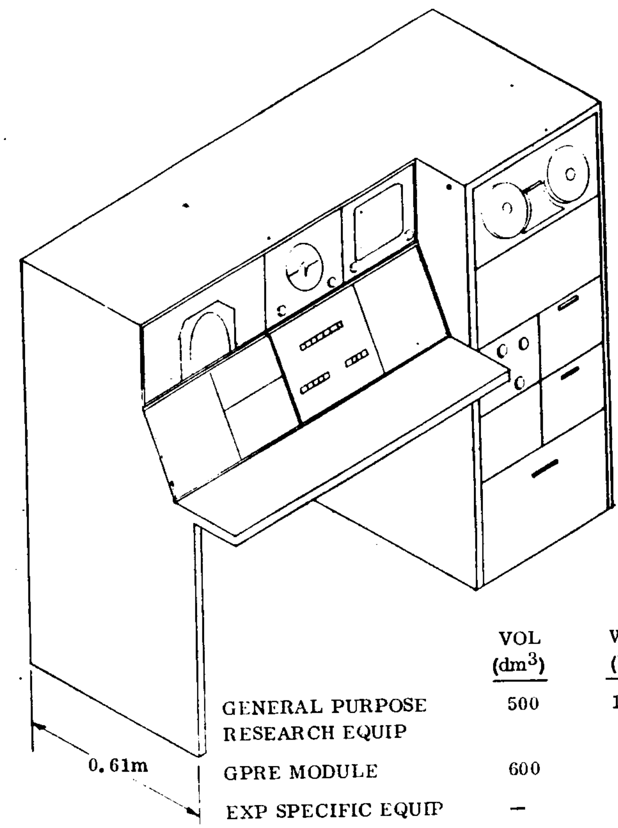


Figure 3-14. MSI COL — Concept H_3, Performance Measurements Laboratory (No Physiological Measurement Capability)

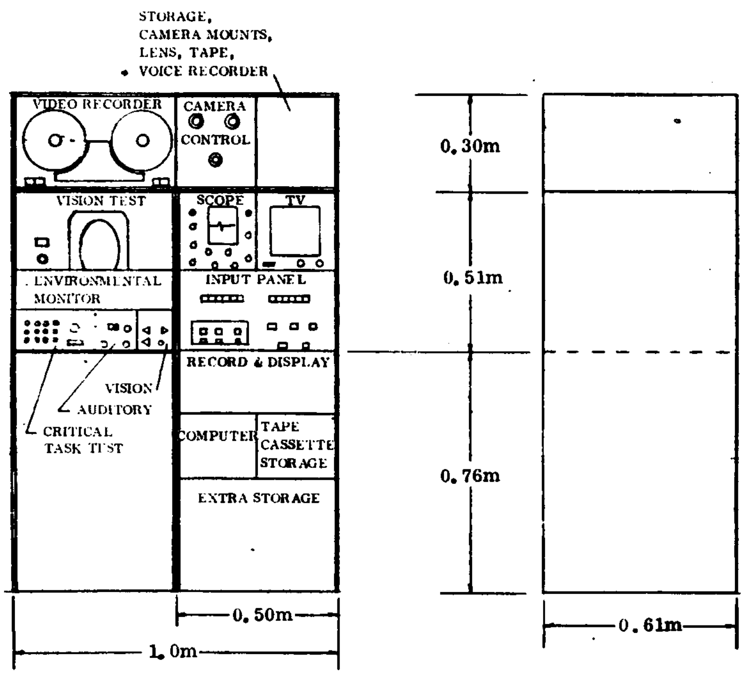


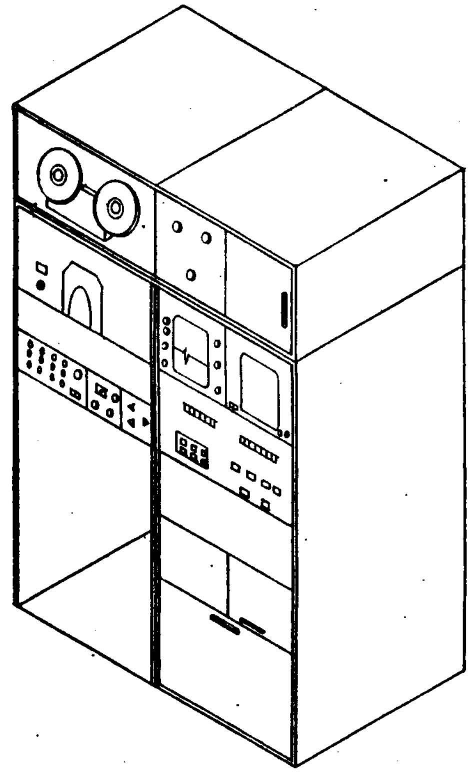


	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	500	187
GPRE MODULE	600	24
EXP SPECIFIC EQUIP	–	–
TOTAL ENVELOPE	1180	211

1.2 – 2.2 – 3.2

Figure 3-15. MSI COL — Concept H_4, Behavioral Measurements Laboratory





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	500	187
GPRE MODULE	728	29
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	960	216

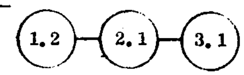
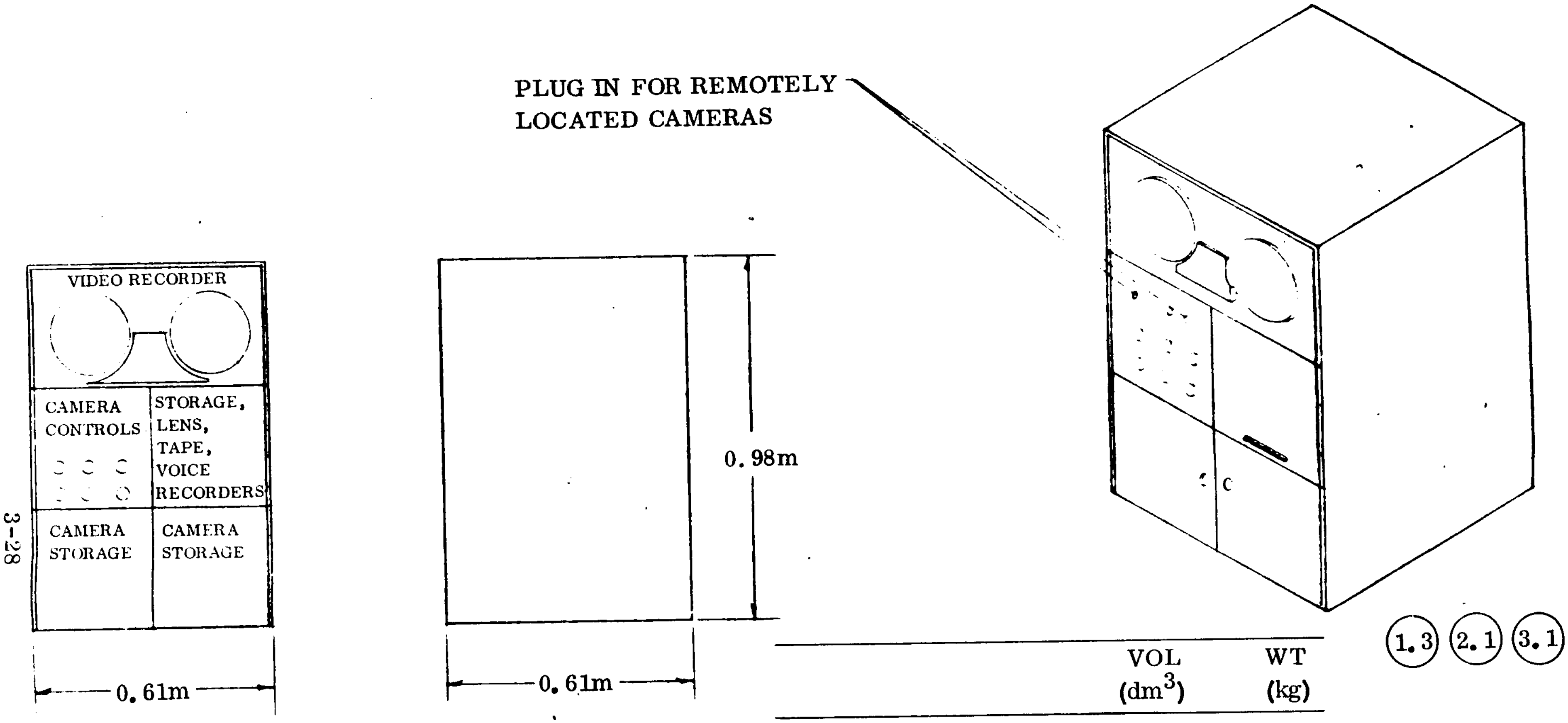
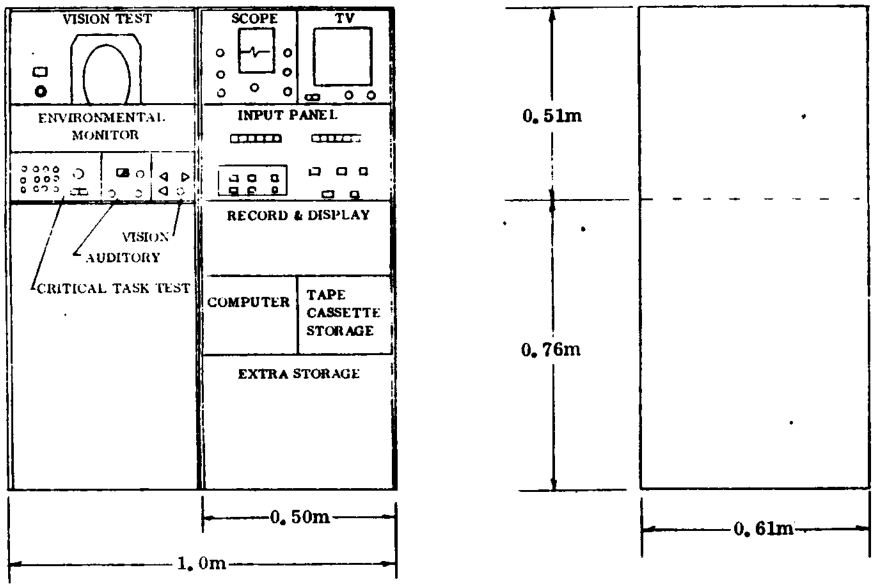


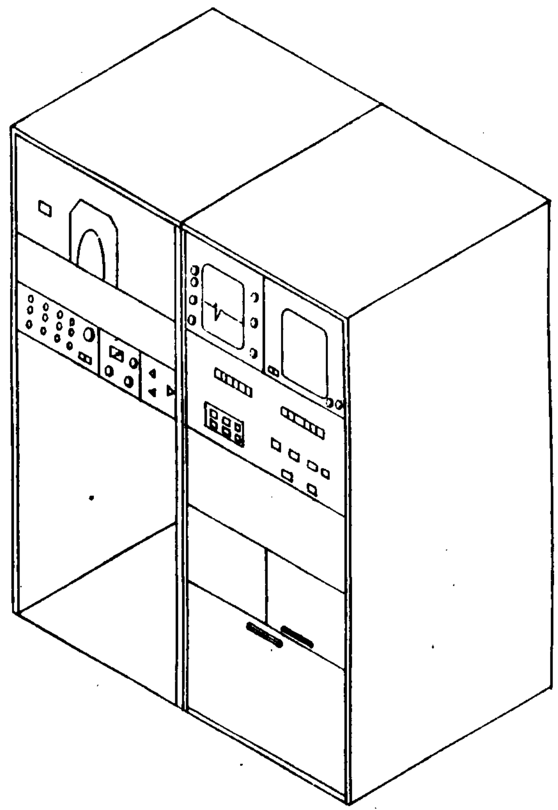
Figure 3-16. MSI COL — Concept H_5, Behavioral Measurements Laboratory



	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	198	69
GPRE MODULE	360	15
EXP SPECIFIC EQUIP	—	—
TOTAL ENVELOPE	360	84

Figure 3-17. MSI COL — Concept H_6, Non-Interference Measurements Laboratory





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	294	118
GPRE MODULE	541	22
EXP SPECIFIC EQUIP	-	-
TOTAL ENVELOPE	774	140

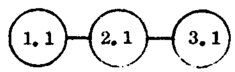


Figure 3-18. MSI COL — Concept H_7, Sensory and Psychomotor Measurements Laboratory

3.4 LIFE SUPPORT AND PROTECTIVE SYSTEM COL LAYOUTS

The preceding definition of general purpose research equipment for the LSPS FPE resulted in four general groups of equipment associated with four general classes of experiments. These are:

I. Liquid-Handling Equipment Experiments

II. Crew-Interfacing Equipment Experiments

III. Gas-Handling Equipment Experiments

IV. Feeding System Equipment Experiments

The liquid-handling and gas-handling equipment experiments (I and III) are very similar, and combining them would be logical. Both are expected to involve tests on experimental prototype liquid- or gas-processing equipment. This equipment can be run using a test-bench-type COL containing a space to place the test article and various facilities for its operation. The gas- or liquid-handling equipment will generally operate automatically after being turned on and will require only occasional attention from the crew for such tasks as manual control actions, data acquisition, sample collection, and sample preparation and storage. The crew member could probably be either erect or seated while attending to these tasks.

The second class of experiments involves crew interfacing equipment (II), which includes tests on articles requiring integral crew involvement, such as pressure suits, commodes, garments, showers, etc. These test articles are experiment-specific and could be quite large and heavy, requiring large spaces for their operation. These experiments should not require a bench-type COL configuration except to provide a small work surface for the crew to write, prepare samples, and do minor assembly or disassmebly tasks. The types of experiments to be done are quite variable; therefore, less general-purpose equipment is included in this COL compared to those for the other three classes of experiments.

The last class of LSPS experiments is that of tests on feeding system equipment (IV). Requirements of these experiments are expected to be between the requirements of 1) the gas- and liquid-handling equipment experiments and 2) the crew-interfacing equipment experiments. Like the crew-interfacing equipment class of experiments, the feeding equipment will require a large degree of crew interaction. However, the equipment should be smaller and crew interaction will generally take place with the crew in a restrained, seated-like, position. An experiment surface will probably be required for many of these experiments, and the supporting equipment will be similar to that required for the liquid-handling equipment experiments.

The approach used in generating potential layouts for these COLs involved varying two configuration parameters as well as considering the four classes of experiments discussed above. The major layout parameters considered are summarized in Table 3-4.

Table 3-4. LSPS COL Layout Parameter Options and Concepts Considered

	1.0 COL Combinations	2.0 Module Configuration	3.0 Crew Interface (Body Position)
POSSIBLE OPTIONS	1.1 † I - Liquid Handling Equipment	2.1 Standard Rack (0.61×0.61 meters in cross-section)	3.1 Standing
	1.2 † II - Crew Interface Equipment		
	1.3 † III - Gas Handling Equipment		3.2 Seated
	1.4 † IV - Feeding System Equipment		
	1.5 I + II	2.2 Custom Shape	
	1.6 I + III		
	1.7 I + IV		
	1.8 I + II + III		
	1.9 I + II + IV		
	1.10 I + III + IV		
	1.11 † I + II + III + IV		
	1.12 II + III		
	1.13 II + IV		
	1.14 II + III + IV		
	1.15 III + IV		

	Concept Designation	Characteristics Assigned to Each Concept (From Above)					
CONCEPTS CONSIDERED † (LAYOUTS DRAWN)	L-1, Fig. 3-22	1.1	I	2.2	Custom	3.2	Seated
	L-2, Fig. 3-23	1.2	II	2.1	Rack	3.1	Standing
	L-3, Fig. 3-24	1.2	II	2.2	Custom	3.1	Standing
	L-4, Fig. 3-25	1.3	III	2.2	Custom	3.2	Seated
	L-5, Fig. 3-26	1.4	IV	2.2	Custom	3.2	Seated
	L-6, Fig. 3-27	1.11	All	2.2	Custom	3.2	Seated
	L-7, Fig. 3-28	1.11	All	2.2	Custom	3.2	Seated
	L-8, Fig. 3-29	1.11	All	2.1	Rack	3.1	Standing

The two major parameters varied are denoted as module configuration and crew interface (body position). The meanings of these options were discussed earlier in Section 3.2.

3.4.1 SPECIFIC LSPS LAYOUT CONCEPTS

3.4.1.1 LSPS COL — Concept L_1. This layout concept, Figure 3-19, is intended to satisfy the liquid-handling equipment class of experiments. It contains an area for various liquid-handling equipment test articles, which have been assumed not to exceed about 0.5 by 0.5 by 0.75 meters (1.6 by 1.6 by 2.5 feet). The configuration is custom- rather than rack-sized and would be addressed by the crew in the seated position if placed on the Spacelab floor as indicated in the drawing. However, it could be raised off the floor about 0.3 meter (0.98 foot) to be conveniently addressed by a standing crewman. The lower module of the COL will fit through the 1.01-meter (40-inch) hatch. Upper and lower modules would be assembled inside the Spacelab to form the configuration shown. The space between these modules would be used for the liquid-handling equipment test articles, and could be enclosed with the environmental shroud if necessary. Facility connections to support the test article are located around the edge of the bench surface. These include water, gases, vacuum, high-temperature cooling fluid, low-temperature cooling fluid, electrical power, data management subsystem bus interconnections, and gas analysis ports. The location of individual items within the configuration is intended only as an approximate representation for conceptual design evaluation. Estimates of weight and volume associated with the concept are shown in Figure 3-19. Weight includes the general-purpose research equipment and weight of the structure to support this equipment. Weight of the experiment-specific equipment is also indicated. This is the test article and its actual weight is unknown at this time.

Four volumes are indicated on the layout drawing. These are 1) volume of the supporting general-purpose research equipment, 2) volume of the upper and lower modules containing the general-purpose equipment, 3) estimated envelope volume required by experiment-specific equipment (the volume between the upper and lower modules that is available for placement of the test article), and 4) total envelope volume of the COL concept (excluding the seated crewman and deployable work surface).

3.4.1.2 LSPS COL — Concept L_2. This layout concept is for the crew-interfacing equipment class of experiments and is shown in Figure 3-20. The amount of general-purpose equipment that can be identified at this time is small, as indicated in the figure. General-purpose equipment is shown contained in a standard rack-type module with a 0.61 by 0.61 meter (2 by 2 foot) cross-section. It could be fitted into a standard rack of this size and positioned about 1 meter off the floor so that equipment could be conveniently attended to by a standing crewman. An experiment-specific storage module is also included to account for the possible large and variable-shaped experiment-specific equipment such as hard pressure suits, commodes, a bicycle ergometer (for performing pressure suit tests), showers, etc. The shape of the storage module shown does not indicate the actual configuration, but merely accounts for its volume. The general-purpose research equipment weighs 97 kg (214 pounds) for this concept, and the estimated weight of the structure to support it is 11 kg (24 pounds). Volume of the general-purpose research equipment is 188 dm^3 (6.6 ft^3), and it is contained in a module requiring 264 dm^3 (9.3 ft^3). The estimated allocation for experiment — specific equipment is 745 dm^3 (26.3 ft^3). The total envelope volume is 1010 dm^3 (35.7 ft^3).

3.4.1.3 LSPS COL — Concept L_3. This concept, Figure 3-21, is for the crew-interfacing equipment experiments. The configuration and dimensions are somewhat customized and include a small work surface for the crew to write on, perform minor assembly tasks, and handle data samples. This COL was intended to be addressed by the crewman in the standing position, and would have to be supported about 1 meter off the floor. Volume of the general-purpose experiment equipment module is 282 dm^3 (10 ft^3) and does not include the volume of the structure between the floor and this module. This concept also includes an experiment-specific equipment storage module, intended to account for volume taken up by such equipment.

3.4.1.4 LSPS COL — Concept L_4. This concept (Figure 3-22) is very similar to concept L_1 and many of the same comments in the discussion of L_1 apply here. It is primarily oriented toward a seated crewman and is custom-shaped to accommodate the required equipment. It is intended to support gas-handling equipment test articles placed between the upper and lower modules containing the general-purpose research equipment. The environmental shroud can be deployed between the upper and lower modules to provide a gas-tight enclosure for the test article if required.

3.4.1.5 LSPS COL — Concept L_5. Concept L_5 (Figure 3-23) is intended to support feeding system equipment experiments. It is configured to accommodate a seated crewman acting as a test subject in conjunction with tests on the feeding system equipment. It consists of an upper and lower module, each of which is custom-shaped to accommodate the general-purpose research equipment. Space between the upper and lower modules is intended to accommodate various test articles. Facilities for some of these test articles such as coolant, liquids, gases, and electrical power may be required and are integrated into the bench surface area. In this concept, the experiment-specific equipment module volume has been assumed to be the total volume between the upper and lower general-purpose equipment modules.

3.4.1.6 LSPS COL — Concept L_6. This concept, Figure 3-24, is the first of three concepts (Figures 3-24 through 3-26) intended to support any of the LSPS experiment classes (I through IV). It can accommodate all general-purpose research equipment needed for any of these classes. However, some of this equipment would be deleted depending on the experiments being conducted. The crew-interfacing equipment class of experiments, for example, needs much less general-purpose equipment and a work bench area is not essential. (See Concepts L_2 and L_3). Thus, in Concept L_6, the upper module, a portion of the lower module, and the work surface could be deleted. For all classes of experiments except those on crew-interfacing equipment, the experiment-specific equipment storage module can be deleted. The concept is based on a seated crewman and a custom shape. For some experiments on feeding system equipment, a work surface larger than the deployable shelf will be desirable for the seated crewman and some equipment in the lower equipment module could be deleted to create leg space for a seated crewman and allow him access to a portion of the bench surface for his experiments.

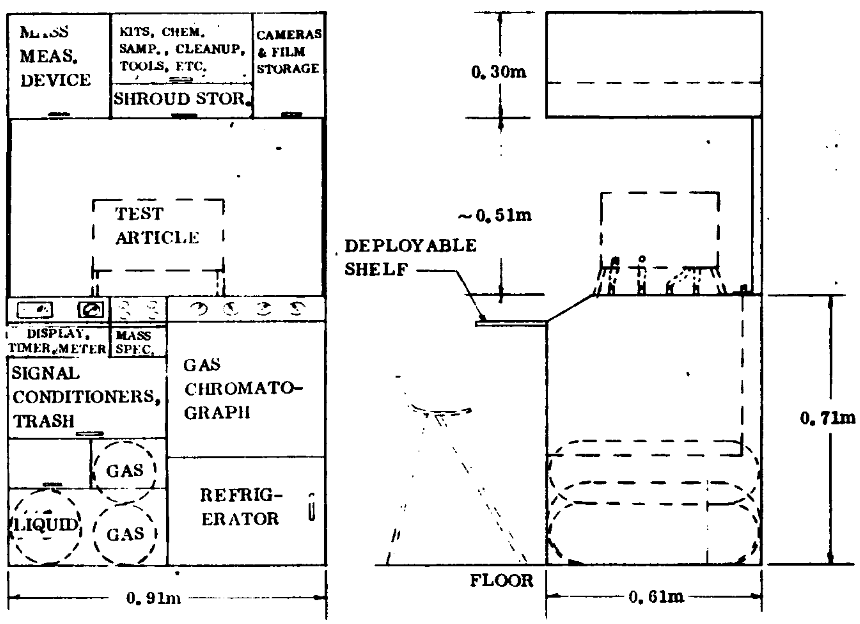
3.4.1.7 LSPS COL — Concept L_7. Concept L_7, shown in Figure 3-25, can accommodate any of the LSPS experiments with minor modifications. It is configured for a seated crewman to have access to the work bench surface area, and is custom shaped to contain all general-purpose research equipment. It allows access to the test article from only the front and left sides of the main module, but this feature makes the implementation of the gas shroud easier. It could be further facilitated by the insertion of a solid partition between the upper and lower modules on the left end of the work bench area. Thus, this concept might be preferred for experiments requiring an environmental shroud if access from the sides was not necessary.

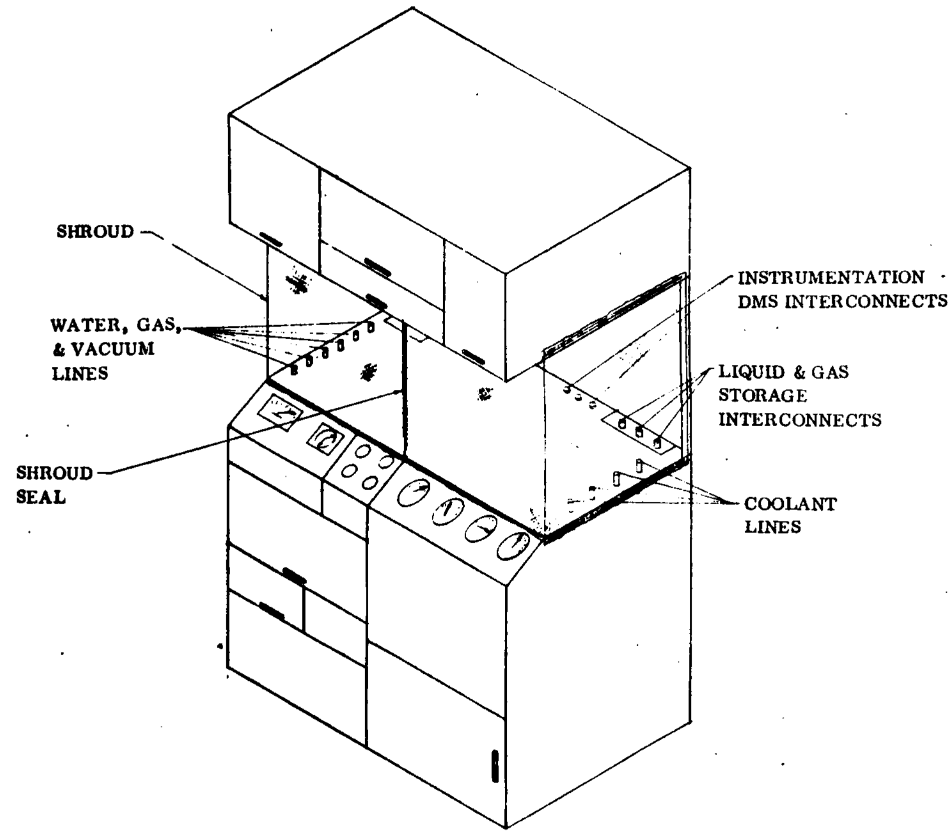
3.4.1.8 LSPS COL — Concept L_8. As shown in Figure 3-26, this concept will accommodate all classes of LSPS experiments and is made up of two standard rack-type modules with a height of 1.07 meters (3.5 feet). Primary crew orientation would be in a standing position. This body position is expected to be acceptable for most experiments on gas- and liquid-handling equipment but not acceptable for some experiments on crew feeding equipment, where a crew restraint (or seat) plus a fold-out work surface might be added. Another option, since the feeding system experiments require less equipment than needed for all the LSPS experiments, would be to delete some of this equipment from the equipment module to leave some leg space under the top surface of the configuration and thus create a portion of this surface for use by a seated crewman while testing a feeding system device. For the crew-interfacing equipment experiments, about one-half of the COL console containing general purpose equipment could be eliminated. Also, for these types of experiments, the experiment-specific equipment module would be included. This concept has the advantage that access to the test article is possible from the top and any sides not blocked by other modules within the Spacelab. One disadvantage is that the environmental shroud will require structural supports if used.

3.4.2 RECOMMENDED LSPS COL LAYOUT CONCEPTS. The concepts that accommodate all LSPS experiments are considered better candidates for integration and further design study than those limited to a single experiment class. These are Concepts L_6, L_7, and L_8. Among these, Concept L_6 appears to be more flexible in that it can be modified to meet the requirements of any of the experiments. The height is more compatible with experiments requiring the seated crew mode of operation than Concept L_8. Also, its two separate (upper and lower) module configuration offers more flexibility in modifying the overall laboratory than Concept L_7.

3.5 SUMMARY TABULATION OF LAYOUT CONCEPTS FOR ALL FPEs

Table 3-5 summarizes the approximate physical characteristics associated with all the conceptual Life Sciences COL layouts.





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	317	165
GPRE MODULE	560	20
EXP SPECIFIC EQUIP	TBD	TBD
TOTAL ENVELOPE	840	185 + ESE

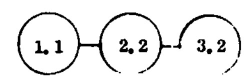
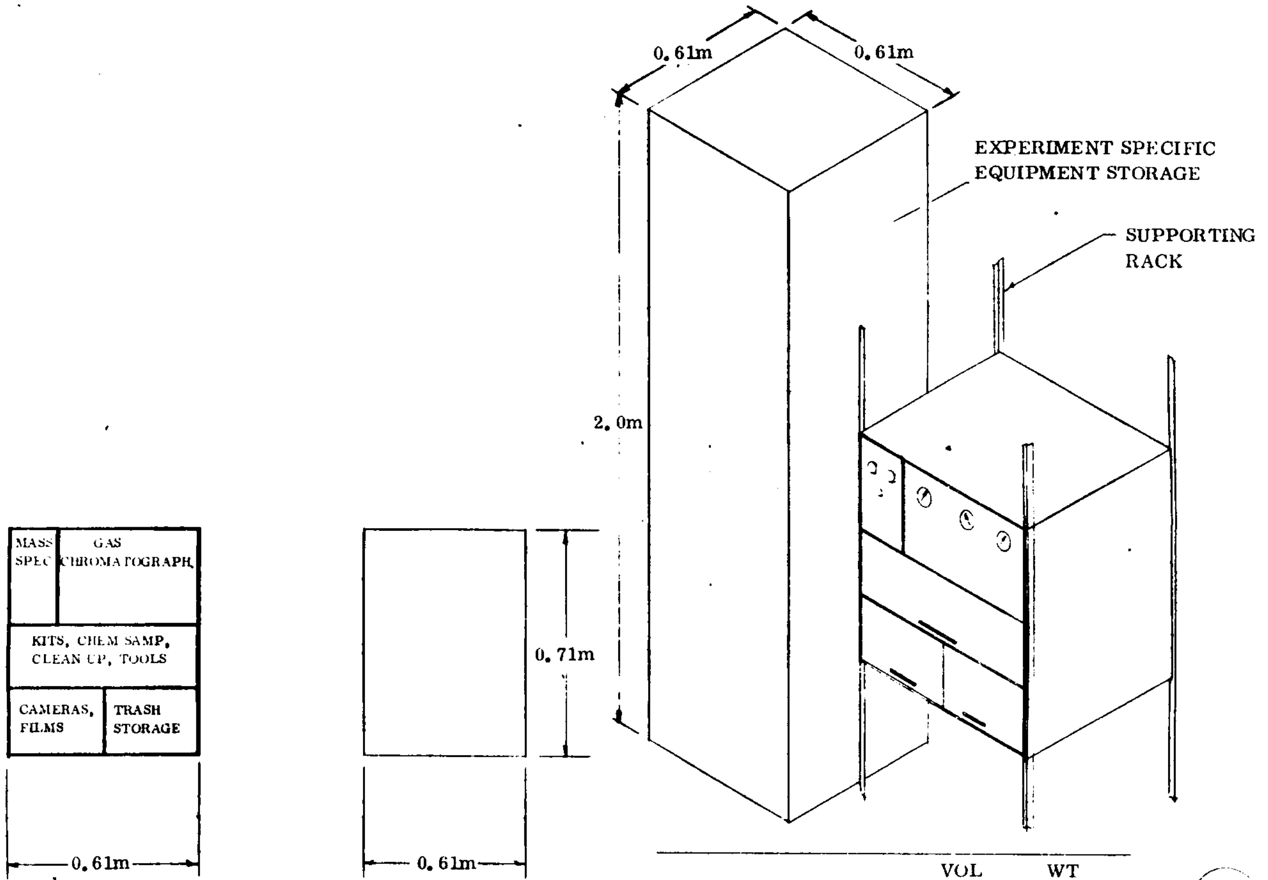


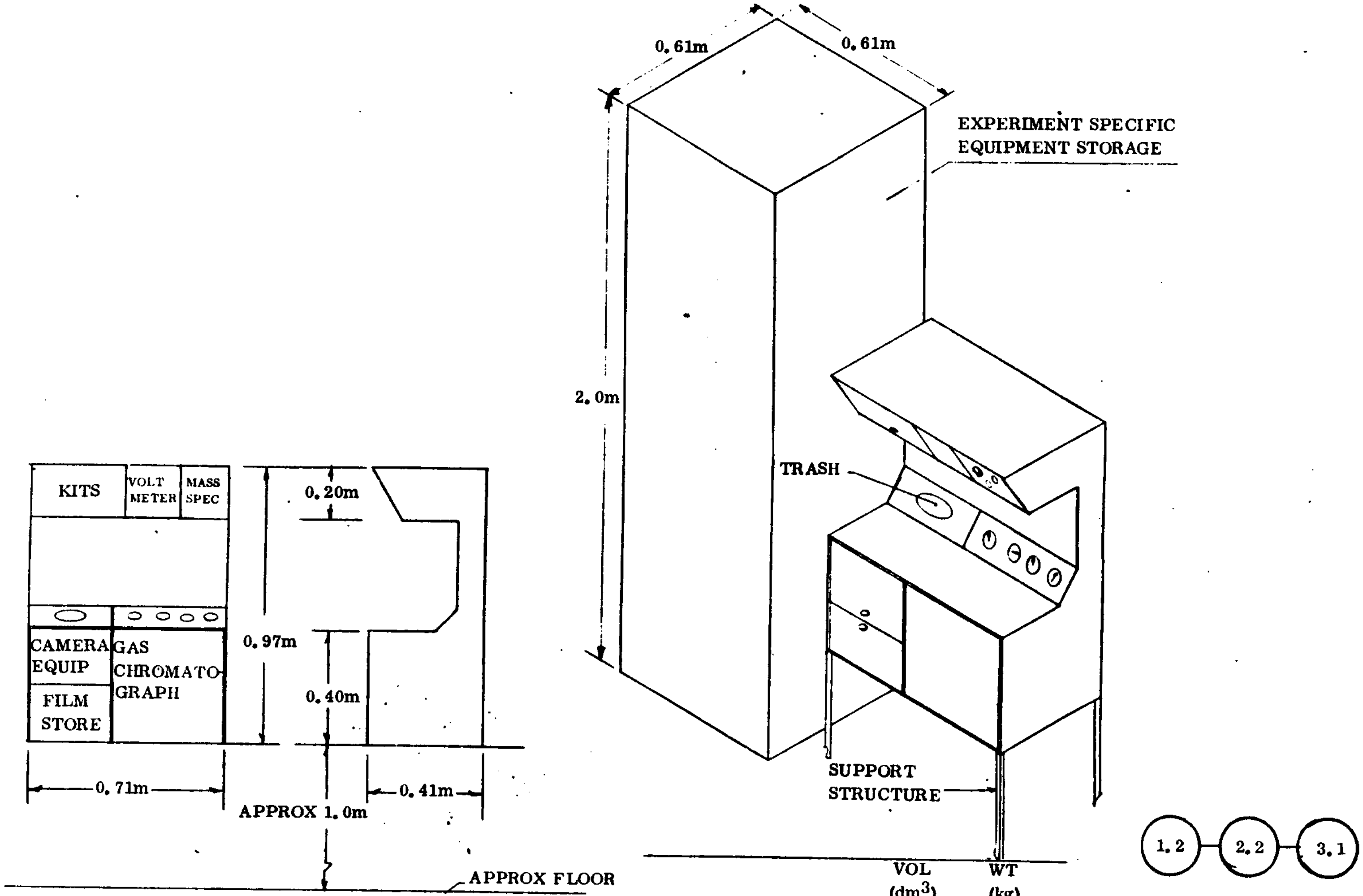
Figure 3-19. LSPS COL — Concept L_1, Accommodates Liquid Handling Equipment Experiments Only



	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	188	97
GPRE MODULE	264	11
EXP SPECIFIC EQUIP	745	30 + ESE
TOTAL ENVELOPE	1010	138 + ESE

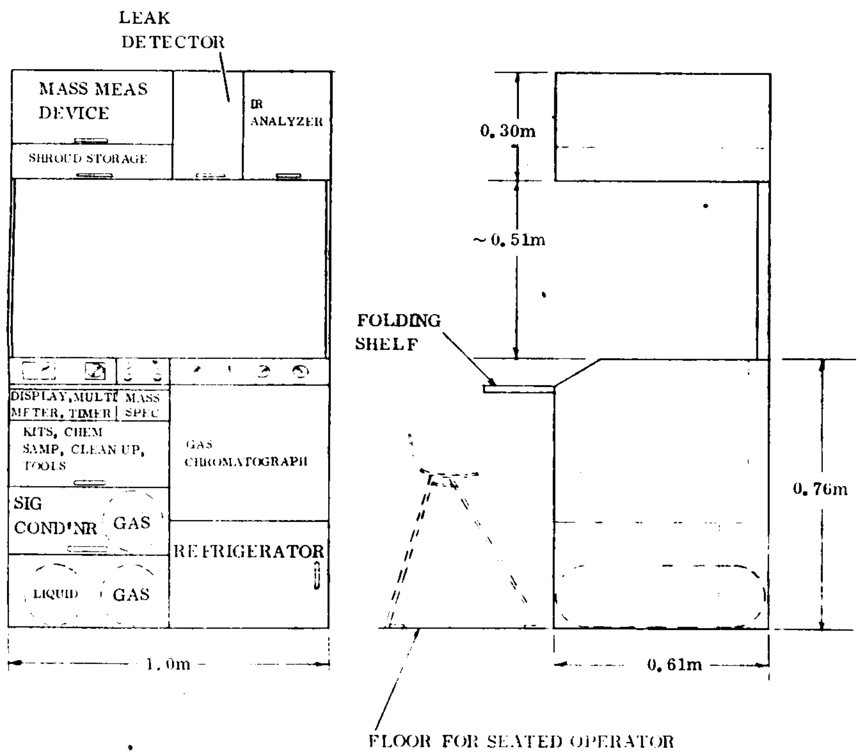
1.2 — 2.1 — 3.1

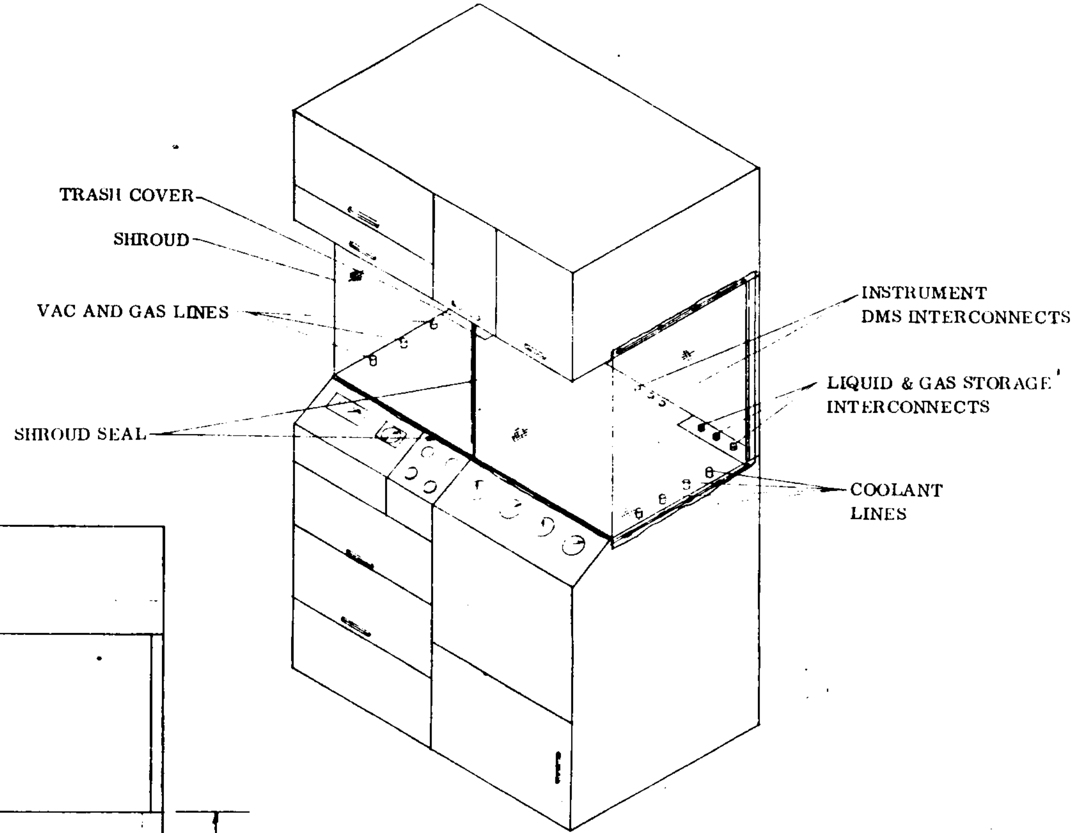
Figure 3-20. LSPS COL — Concept L_2, Accommodate Crew Interfacing Equipment Only



	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	188	97
GPRE MODULE	282	13
EXP SPECIFIC EQUIP	745	30 + ESE
TOTAL ENVELOPE	1027	140 + ESE

Figure 3-21. LSPS COL — Concept L_3, Accommodates Crew Interfacing Equipment Experiments Only

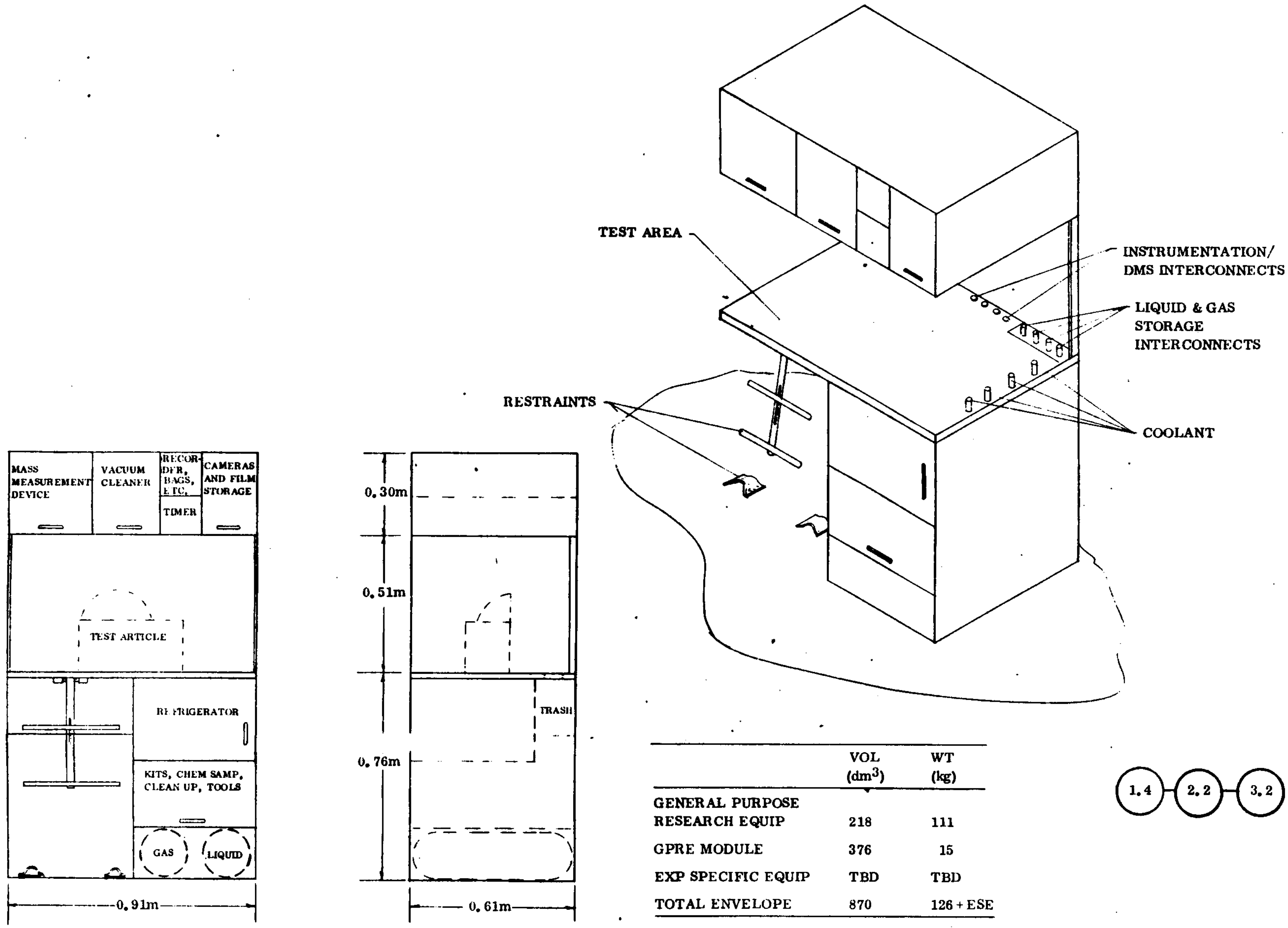




	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	369	156
GPRE MODULE	645	26
EXP SPECIFIC EQUIP	TBD	TBD
TOTAL ENVELOPE	945	182 + ESE

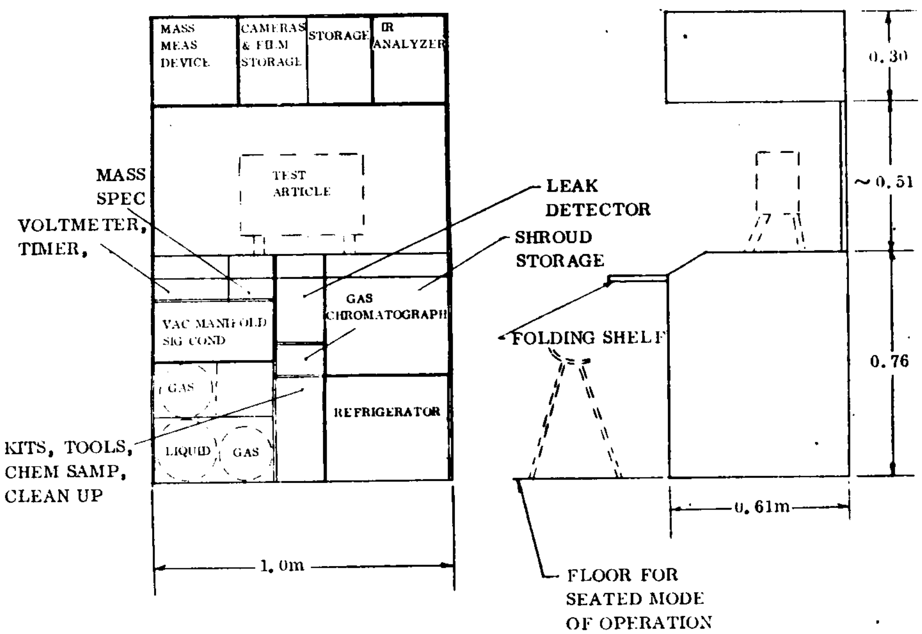
1.3 – 2.2 – 3.2

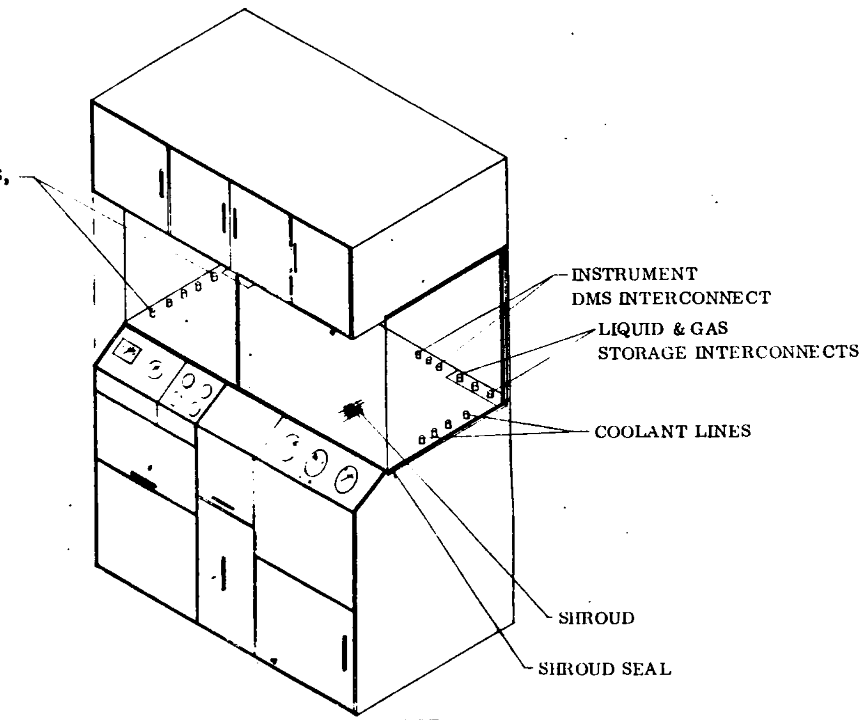
Figure 3-22. LSPS COL — Concept L_4, Accommodated Gas Handling Equipment Experiments Only



	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	218	111
GPRE MODULE	376	15
EXP SPECIFIC EQUIP	TBD	TBD
TOTAL ENVELOPE	870	126 + ESE

Figure 3-23. LSPS COL — Concept L_5, Accommodates Feeding System Equipment Experiments





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	400	189
GPRE MODULE	648	26
EXP SPECIFIC EQUIP	745	30 + ESE
TOTAL ENVELOPE	1705	245 + ESE

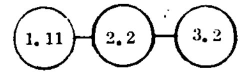
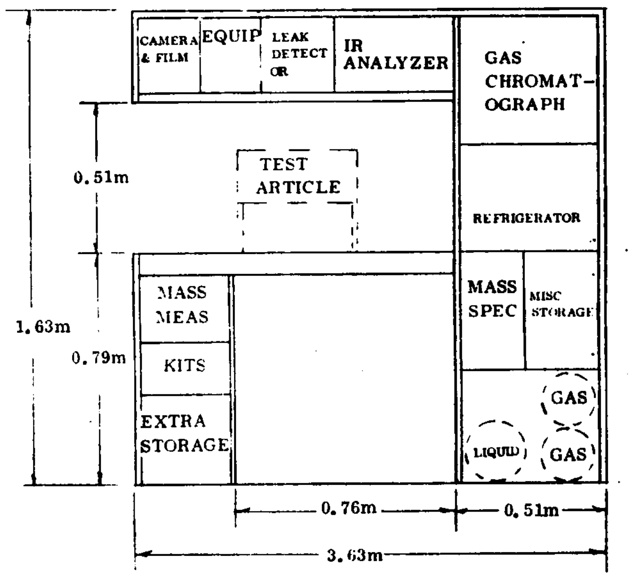
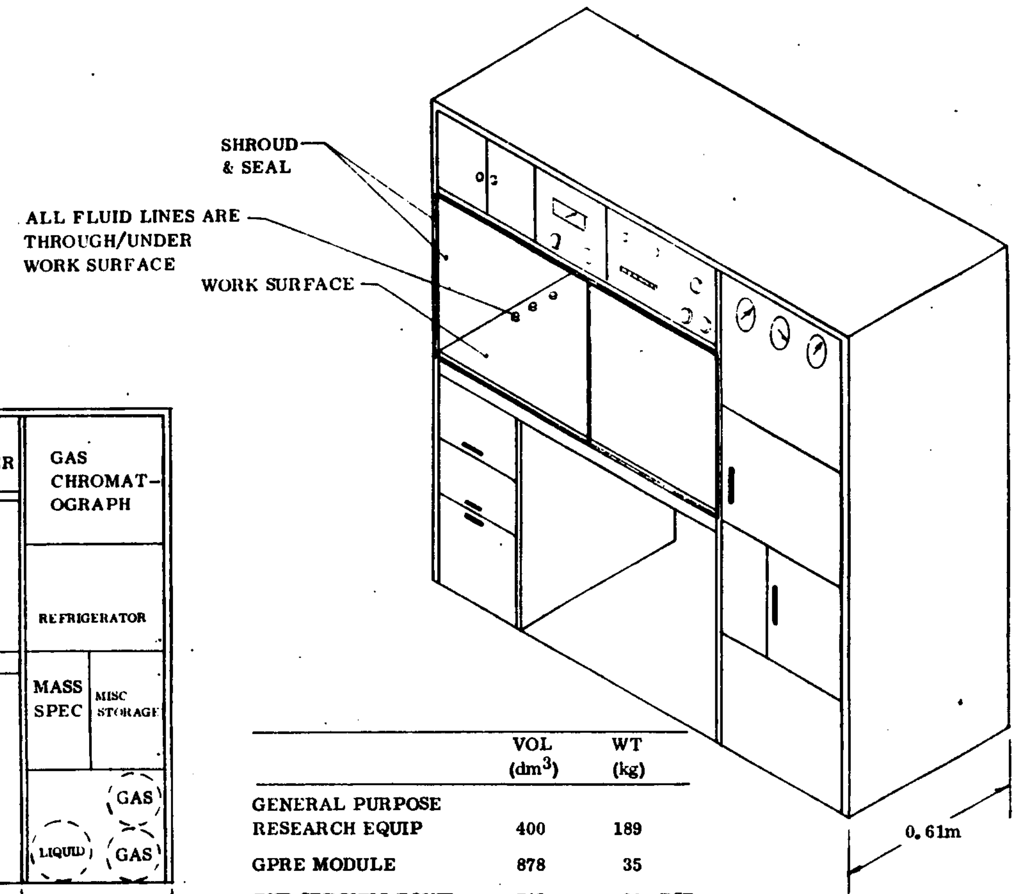


Figure 3-24. LSPS COL — Concept L_6, Accommodates All LSPS Experiments





	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	400	189
GPRE MODULE	878	35
EXP SPECIFIC EQUIP	745	30 + ESE
TOTAL ENVELOPE	2365	254 + ESE

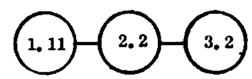
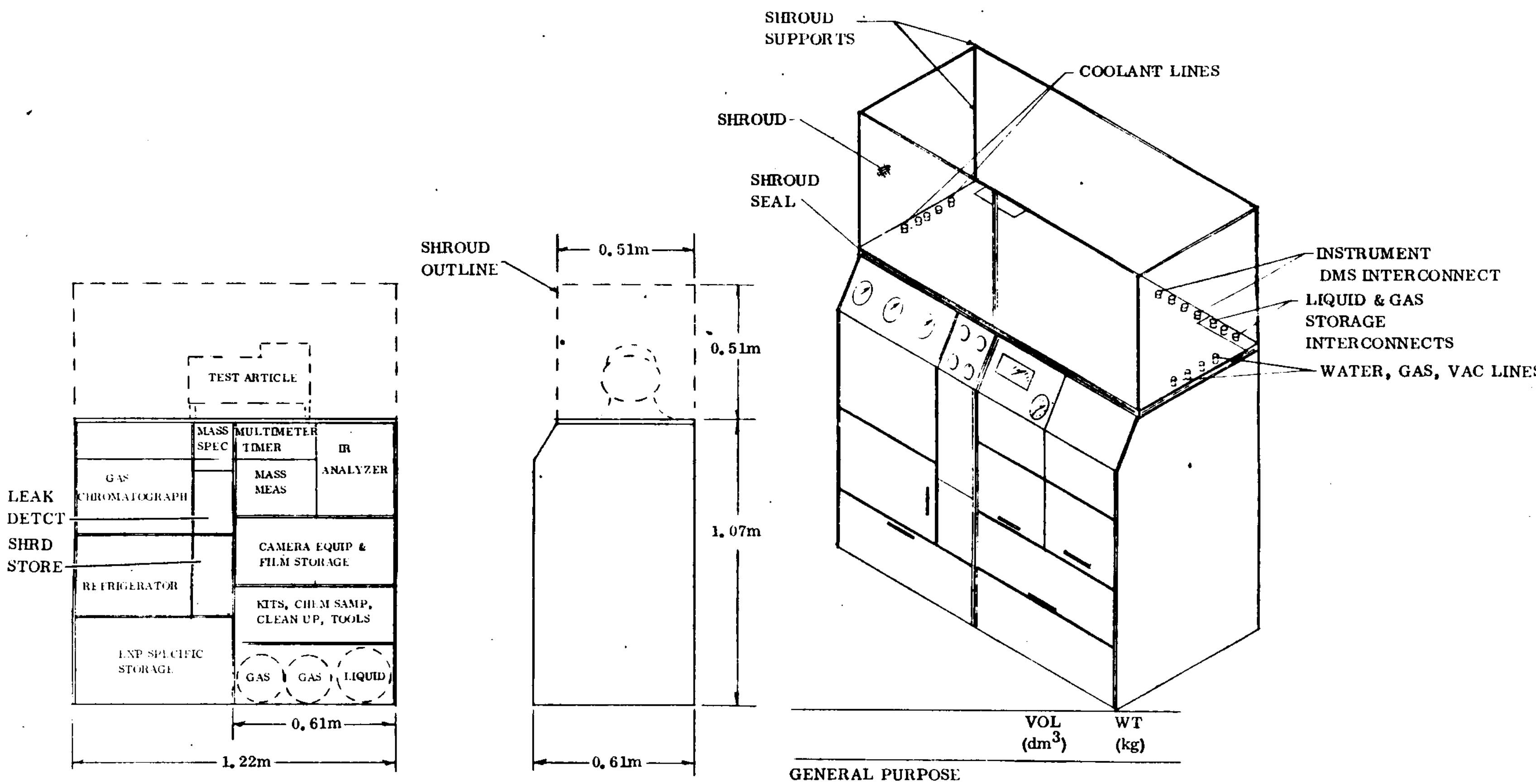


Figure 3-25. LSPS COL — Concept L_7, Accommodates All LSPS Experiments



	VOL (dm^3)	WT (kg)
GENERAL PURPOSE RESEARCH EQUIP	400	189
GPRE MODULE	800	32
EXP SPECIFIC EQUIP	745	30 + ESE
TOTAL ENVELOPE	1925	251 + ESE

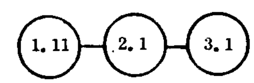


Figure 3-26. LSPS COL — Concept L_8, Accommodates All LSPS Experiments

Table 3-5. COL Layout Characteristics Summary

Layout Concept	Weight, kg: Research Equipment[1]	Weight, kg: Module Structure	Weight, kg: Total	Volume, dm³: Research Equipment	Volume, dm³: Modules: Research Equipment	Volume, dm³: Modules: Experiment Specific[2]	Volume, dm³: Module Envelope	Total Power, watts[3]	Module Configuration: Custom	Module Configuration: Standard	Crew Interface: Standing	Crew Interface: Seated	Isolation: Glove Box	Isolation: Arm Slots	Isolation: Shroud	Isolation: Open	Envir. Control System: Open	Envir. Control System: Closed	Envir. Control System: None
Biomed/Biology Common Lab																			
Concept C-1 ▲	288	53	341	1031	1322	-	1700	1373	x			x	x					x	
C-2 ▲	225	53	278	843	1322	-	1700	1210	x			x	x					x	
C-3 ▲	190	29	219	610	730	-	730	988	x			x				x			x
Biomedicine																			
Concept B-1	190	27	217	610	675	-	1240	988	x			x				x			x
B-2	190	37	227	610	935	-	935	988		x	x					x			x
Biology																			
Concept F-1	271	48	319	973	1200	-	2560	1373	x			x		x				x	
F-2	264	48	312	964	1200	-	2560	1373	x			x				x	x		
F-3	271	46	317	973	1145	-	1145	1373		x	x					x		x	
F-4	172	31	203	722	771	-	1890	1105	x			x		x				x	
F-5	166	37	203	673	930	-	2800	1057	x			x	x					x	
F-6	172	63	235	746	1576	-	2168	1459	x			x				x		x	
Man-Systems Integ.																			
Concept H-1	92	25+(25e)	142+e	340	635	635	1370	608+e		x	x								
H-2 ▲	69	11+(20e)	100+e	198	268	510	778	558+e		x		x							
H-3	69	9+(21e)	99+e	198	210	530	740	555+e		x	x								
H-4	157	24	211	500	600	-	1180	954		x		x							
H-5	187	29	216	500	728	-	960	954	x		x								
H-6	69	15	84	198	360	-	360	555	x		x								
H-7	118	22	140	294	541	-	774	399	x		x								
Life Supp./Prot. Systems																			
Concept L-1	165	20	185+e	317	510	-	840	662+e	x			x			x				
L-2	97	11+(30e)	138+e	188	264	745	1010	635+e		x	x								
L-3	97	13+(30e)	140+e	188	282	745	1027	635+e	x		x								
L-4	156	26	182+e	369	645	-	945	544+e	x			x			x				
L-5	111	15	126+e	218	376	-	870	462+e	x			x							
L-6 ▲	189	26+(30e)	245+e	400	648	745	1705	832+e	x			x			x				
L-7	189	35+(30e)	254+e	400	878	745	2365	832+e	x			x			x				
L-8	189	32+(30e)	251+e	400	800	745	1925	832+e	x			x			x				

[1] General purpose research equipment items within the COL - as opposed to special test articles, etc., see item "2".
[2] Experiment specific includes items such as test units for LS/PS or MSI research.
[3] Power value is maximum all general purpose research equipment on - used only as a preliminary indicator.
e Experiment specific equipment.
▲ Tentative baseline selections.

SECTION 4

FINAL COL CONCEPTUAL DESIGNS (TASK C)

4.1 GUIDELINES FOR FINAL CONCEPTUAL DESIGNS

Prior to the Task C phase of this study, the NASA Life Sciences Payload Integration team reviewed the layouts developed during Task B and described in Section 3. NASA selected those concepts for which final conceptual designs and integration studies were to be completed by Convair. NASA selected one COL concept for each major FPE area, and specified several limited-capability COLs to be developed for biomedical research. A summary of the guidelines issued by NASA at this juncture are described below in Section 4.1.1. Following this, in Section 4.1.2, several aspects of the approach used in defining the biomedical COLs are presented.

4.1.1 <u>NASA GUIDELINES FOR CARRY-ON LABORATORY CONCEPTS</u>. NASA specified three weight ranges for which conceptual COL were to be developed:

Category C Laboratories of less than 23 kg (50 lb)
Category B Laboratories of less than 91 kg (200 lb)
Category A Laboratories of 227 to 318 kg (500 to 700 lb).

To design Category C packages in the 23 kg (50 lb) range, the following four priorities were to be considered: 1) vestibular functions, 2) body fluid composition and electrolyte functions, 3) cardiovascular functions, and 4) physiological functions. However, only the first two priorities were to be specifically used in the design of the Category C COLs. The Category C laboratories were to be packaged to fit into compartments within the supporting spacecraft measuring 43 cm wide by 36 cm high by 51 cm deep (17 by 14 by 20 inches). The 43 by 36 cm surface was to be the accessible front side of this package.

To design Category B COLs in the 91 kg (200 lb) range, the following priorities and grouping by research areas were to be used:

Group 1 — Vestibular
Body Fluid Composition and Electrolyte Functions
Cardiovascular Functions

Group 2 — Hemodynamic Functions
Blood Morphology Functions
Blood Chemistry Functions

Group 3 — Metabolic Functions
Gastrointestinal Functions
Excretory Functions
Pulmonary Functions
Microbiology Functions
Neurology Functions

For the COL Category B study, Convair was to consider all of these groups but only deal with the development, including conceptual designs, of Group 1.

In the design of Category B and C COLs, every effort was to be made to use common equipment.

The life sciences layout concepts to be continued as Category A COLs were Concepts C_1, H_2, and L_6 as presented in Section 3 (Figures 3-1, 3-13, and 3-24). However, several minor changes in the layout concepts were to be implemented. Concept C_1 was to include both biomedical and biological research capability on the same mission. In MSI Concept H_2, human sensory and physiological measurement equipment was to be omitted, but equipment for photography and audio taping was to be added. In LSPS Concept L_6, the accommodations for feeding system experiments were to be omitted.

4.1.2 <u>APPROACH USED IN DEFINING THE FINAL CONCEPTUAL DESIGNS OF THE COL.</u> The sections to follow describe the biomedical research areas and requirements for the Category C and B COLs. These COLs were introduced at this point in the program (Task C), whereas the Category A COLs were studied earlier and conceptual layouts had been evaluated and selected. Following the discussion of the Category C & B COL research areas and requirements, the conceptual designs of the COLs are described, starting with the newly defined Category C COLs and working up in increasing capability to the Category A COL which combines biomedical and biological research capability. This order of presentation most nearly follows the order in which the study progressed and retains the continuity leading from the research requirements for the Category C and B COLs to the physical description of these COLs. It appeared logical to start with the small, relatively simple Category C COLs and build toward the larger, more complex laboratories. In this manner, the equipment for the small laboratories conceived for relatively specific research functions could be combined to create the larger, more comprehensive laboratories. It is hoped that this order of presentation will also aid the reader in easily building up to an understanding of the total functional and equipment capabilities of the larger COLs.

An attempt was made throughout the conceptual design activity to utilize common research equipment. This applied not only to the COLs for biomedical research but for all FPEs. For example, where possible, the same equipment item was used for the biomedical, biological, LSPS, and MSI COLs. All such equipment items are defined in detail in Volume III of this report entitled "Preliminary Equipment Item Specification Catalog". In several cases, common equipment items were not used for the various COLs, and two such cases which bear explanation are discussed below.

The first exception relates to several kits used in the Category C COLs compared to those used in the Category A & B COLs. During the previous equipment definition task, described earlier in Section 2, a hematology kit (E.I. C106) and a human physiology kit (E.I. C110C) were defined. These kits were fairly comprehensive, the hematology kit containing items to satisfy both blood and urine acquisition functions and the physiology kit containing physical examination as well as electrophysiological monitoring equipment. These kits were suitable for use in both the Category A and B COLs but not the Category C COLs. The Category C laboratories were limited to 23 kg (50 lb) and the research capabilities of these laboratories were more specific than those of the Category A & B COLs. For this reason, smaller, more specific kits were defined. These were designated as a blood acquisition kit, urine acquisition kit, and physical examination kit. The blood and urine acquisition kits contain many of the items contained in the hematology kit and the physical examination kit contains items identical to those in the human physiology kit. A summary of the items in each of the aforementioned kits is given in Table 4-1.

A second exception to the use of common equipment in the COLs is the use of the blood gas analyzer (E.I. C85) and the blood sample processor centrifuge (E.I. C189). in the biomedical Category B COL compared to use of the automated potentiometric electrolyte analyzer (E.I. C188) in the Category C and A COLs. The Category B COL is described in Section 4.2.3, and could have been designed within the weight constraint but with a different packaging arrangement to employ the automated potentiometric electrolyte analyzer. However, instead the design purposely demonstrates the option of the use of a blood gas analyzer and the blood sample processor centrifuge to arrive at a research capability that could have been provided by the automated potentiometric electrolyte analyzer.

Table 4-1. Comparison of Kits and Their Contents for the Category A and B versus Category C Biomedical COLs

KITS & CONTENTS USED IN THE CATEGORY B & A COL'S	KITS & CONTENTS USED IN THE CATEGORY C COL'S
HEMATOLOGY KIT Alcohol Band Aids Cotton Swabs Counter, Differential Counter, Tally Cover Slip Critoseal Gauze Hemacytometer Hemoglobinometer Labstix Lancets Luer Adapters Needles Pipettes Slides Syringes Tourniquet Tubes	BLOOD ACQUISITION KIT Alcohol Band Aids Cotton Swabs Hemoglobinometer Lancets Needles Slides Syringes Tourniquet URINE ACQUISITION KIT Labstix Needles Syringes Urine Storage Bags
HUMAN PHYSIOLOGY KIT Counter Cuff, Blood Pressure Electrodes, ECG, EEG, etc. Flowmeter, Doppler Harness, Electrophysiology Labstix Oto-Opthalmascope Respirometer Sphygmomanometer Spirometer Mouthpieces Stethoscope Thermistor Thermometer Tuning Fork	PHYSICAL EXAMINATION KIT Cuff, Blood Pressure Flowmeter, Doppler Oto-Opthalmascope Stethoscope Thermometer Tuning Fork

4.2 BIOMEDICINE/BIOLOGY COL CONCEPTUAL DESIGNS

4.2.1 DISCUSSION OF UPDATED RESEARCH AREAS AND REQUIREMENTS FOR THE COLs. NASA guidelines for the Task C activity were presented in Section 4.1, including the revised research area priorities for the COLs. An analysis was next performed to define candidate research options that could be considered for each high priority research area designated in the guidelines. A major part of this analysis consisted of the review of Skylab research missions to identify research objectives and equipment applicable to the COL missions. When such applicable research procedures and equipment were found, they were used for the COLs. For example, Skylab data provided the detailed definition of body fluid composition and electrolyte functions, blood morphology, and blood chemistry functions. Special blood and urine sample acquisition and storage equipment developed for Skylab missions could be considered for use on the COLs. Some research measurements and equipment developed for Skylab studies of vestibular and cardiovascular functions could also be employed. Other equipment, such as the rotating litter chair required for the M131 Human Vestibular Function Studies, were too large for inclusion, so other research options were generated.

4.2.1.1 Vestibular Function Research. Table 4-2 lists the factors considered in determining a logical COL research mission for vestibular functions, which was the first priority research area. In accordance with Task C NASA guidelines, the research of vestibular functions was to be direct to the study of basic mechanisms causing vestibular disturbance and related impaired performance in space crews. The preflight conditioning exercises, as indicated in Table 4-2, have not prevented space crew vestibular disturbances in some cases. The findings to date therefore do not preclude the possibility that the transient vestibular disturbances encountered in space crews are due to causes other than direct effects of the altered inertial environment in space acting on the vestibular system. Similar transient vestibular disturbances occur in persons exposed to inertial force fields in their usual earth-bound environment.

The causes of such disturbances in ground personnel have been related to vasomotor factors, allergic manifestations, fluid pressure changes, electrolyte changes, fluid retention, etc., which cause deformation of the endolymphatic duct within the vestibular system. Relief from the symptoms of this disturbance has been obtained in various ways such as use of diuretics, low-salt diets, antihistamines, agents causing changes in vestibular tonus, and avoidance of head motions. Exposure to weightlessness is known to cause immediate removal of hydrostatic pressure in blood and other body fluid compartments that normally exist in response to gravitational forces. There is no such immediate change in blood colloidal osmotic pressure as a result of exposure to weightlessness. Consequently, the resulting unbalanced forces between colloidal osmotic pressure and blood, interstitial, lymphatic, and intracellular fluid pressures will evoke a prompt shift of fluid into the vascular bed. The increased circulating blood volume will tend to induce compensatory diuresis to excrete excess fluids and contained proteins and electrolytes mediated through altered renal control functions and altered cell membrane diffusion gradients. The abrupt removal of hydrostatic pressures with first exposure to weightlessness also causes prompt changes in blood distribution.

Table 4-2. Research Options and Requirements, Vestibular Functions — Basic Mechanisms Causing Disturbance

VESTIBULAR FUNCTION RESEARCH OPTIONS	REQUIREMENTS/MEASUREMENTS/EQUIPMENT	REMARKS
•REPEAT SKYLAB EXPT. M 131		
PERCEPTUAL ACUITY IN SPACE	ROTATING LITTER CHAIR	TOO HEAVY FOR CARRY-ON LABORATORY. CAN BE USED AS "EXPERIMENT SPECIFIC".
ORIENTATION IN SPACE	TEST GOGGLES	CAN BE USED FOR SEMIQUANTITATIVE MEASUREMENT WITHOUT ROTATING LITTER CHAIR.
SUBJECT SUSCEPTIBILITY TO REFLEX DISTURBANCE (CORIOLIS)	MOTION SICKNESS INDEX	CAN BE USED BY TRAINED OBSERVER.
•VESTIBULAR SYSTEM HABITUATION		SKYLAB CREW PREFLIGHT PREPARATION HAS NOT PREVENTED VESTIBULAR DISTURBANCES IN SOME CASES. NEW TECHNIQUES MAY BE REQUIRED.
PREFLIGHT CREW TRAINING N.A.M.I. SEQUENTIAL HEAD TURN EXERCISES	GROUND FACILITY	
IN-FLIGHT N.A.M.I. SEQUENTIAL HEAD TURN EXERCISES	OCULOGYRAL ILLUSION MEASUREMENT DEVICE	OCULOGYRAL ILLUSION BOX CAN BE PROVIDED IN CARRY-ON LAB.
•ACUTE FUNCTIONAL LABYRINTHINE DISTURBANCE (E.G., DILATION OF ENDOLYMPHATIC SYSTEM - MENIERE'S SYNDROME)		
DISTURBED PRESSURE GRADIENTS BETWEEN BLOOD, INTERSTITIAL & LYMPH FLUID COMPARTMENTS	BLOOD PRESSURE COLLOIDAL OSMOTIC PRESSURE } M112 PLASMA PROTEINS } M112 BLOOD ELECTROLYTES - M071	
COMPENSATORY DIURESIS & ALTERED BODY FLUID COMPARTMENT VOLUMES & CELL MEMBRANE DIFFUSION GRADIENTS	ANGIOTENSIN } M073 ALDOSTERONE } M073 URINE COMPOSITION & VOLUME } M073 RADIOISOTOPE TRACER STUDIES } M073 BLOOD GAS CHANGES BLOOD PH & BUFFER RESERVE CHANGES	SKYLAB-AUTOMATED SAMPLE PROCESSING FOR PRESERVATION -70°C FREEZER FOR BLOOD, (PLASMA & FORMED ELEMENTS) -20°C FREEZER FOR URINE, WILL ENABLE RETURN OF SAMPLES FOR TESTS SHOWN.
SIGNS & SYMPTOMS - VERTIGO - NYSTAGMUS - PAST POINTING - NAUSEA, VOMITING, ETC.	TRAINED OBSERVER WITH PHYSICAL EXAMINATION KIT & LOG BOOK MOTION SICKNESS INDEX	CAN BE PROVIDED IN CARRY-ON LABORATORY.

For example, when the hydrostatic pressure gradients normally present in the neck arteries of man standing or sitting in a one-g field are removed by exposure to weightlessness, there will be a tendency to promote increased arterial blood flow to the head region for any given level of systolic blood pressure. However, removal of these forces of gravity, which normally exert a downward pull on blood within the head and neck veins, will tend to decrease venous return blood flow toward the heart. Increased fluid volume in expandable structures in the head region would therefore be expected ot occur when exposed to weightlessness and to persist until vasomotor reflex activity and cardiac output adaptation restore normal blood circulation to the structures. Such circulatory requirements would be necessary throughout the cardiovascular system. These zero-g induced changes in circulation, cardiovascular reflex activity, body fluid volume/pressure relationships, and body protein and electrolyte balances could conceivable cause distortion of the endolymphatic organ within the vestibular system of unadapted space crews. The resulting acute reversible labyrinthine functional disturbances noted in space crews could result from these indirect effects of weightlessness. Such effects may be assessed through pressure measurements, flow measurements, bioassay of body fluids, fluid compartment volume measurements, and measurement of renal control functions correlated in time with signs and symptoms of vestibular disturbance in the space personnel under study. The measurement and equipment requirements for such research on the basic causes of vestibular changes in space are summarized in Table 4-2. The equipment items for examining hemodynamic, cardiovascular, and body fluid changes in weightlessness are employed in biomedical carry-on laboratories C_1 and C_3 as shown later in Tables 4-5 and 4-7, respectively. In these laboratories, the above equipment items may be utilized not only for examination of electrolytes, urine composition, and cardiac functions, but also to search for related causes of the transient vestibular disturbances noted in space crews.

4.2.1.2 Body Fluid Composition and Electrolyte Function Research. Review of Skylab data provided a comprehensive description of fluid and electrolyte measurements and equipment required for acquiring, processing, preserving, and returning blood and urine samples for delayed ground analysis to obtain these measurements. The sample management equipment developed for Skylab has weight and size characteristics compatible with the COLs. In addition, NASA is developing an automated potentiometric electrolyte analyzer to provide onboard blood and urine electrolyte measurements, blood gas measurements, and pH determinations. This device enables real-time measurements, such as those on blood gases, that cannot be handled by delayed ground analysis of preserved samples. Volume and weight of the automated potentiometric electrolyte analyzer are also such that it can be considered for use in COL missions. Reserach options, measurements, and equipment requirements considered for the COLs in the research area body fluid composition and electrolyte functions are tabulated in Table 4-3.

4.2.1.3 Cardiovascular Function Research. Skylab data provided descriptions of electrocardiographic and vectorcardiographic data acquisition equipment items that fell within the weight and size ranges compatible for use in the COLs. The inventory

Table 4-3. Research Options and Requirements, Body Fluid Composition and Electrolyte Functions

BODY FLUID COMPOSITION & ELECTROLYTE FUNCTION RESEARCH OPTIONS	REQUIREMENTS/MEASUREMENTS	REMARKS
• <u>DELAYED GROUND ANALYSIS OF THE FOLLOWING ELEMENTS IN BLOOD AND/OR URINE</u> ADRENOCORTICOTROPIC HORMONE (ACTH) 17-HYDROXY-CORTICOSTERONE (CORTISOL) ANGIOTENSIN II RENIN ALDOSTERONE ANDIDIURETIC HORMONE (ADH) EPINEPHRINE NOREPINEPHRINE URINE ELECTROLYTES (Na^+, K^+) URINE OSMOLALITY PLASMA OSMOLALITY EXTRACELLULAR FLUID VOLUME TOTAL BODY WATER SERUM THYROCALCITONIN SERUM THYROXINE HYDROCORTISONE KETOSTEROIDS INSULIN GROWTH HORMONE THYROID STIMULATING HORMONE PLASMA ELECTROLYTES - SODIUM - POTASSIUM - CALCIUM - CHLORIDE - MAGNESIUM - PHOSPHORUS - CREATININE - HYDROXYPROLINE	INTAKE/OUTPUT RECORDS AND BLOOD & URINE SAMPLE ACQUISITION & PRESERVATION FOR GROUND ANALYSIS PER SKYLAB M071 - MINERAL BALANCE " M073 - BIOASSAY OF BODY FLUIDS	DAILY LOG. SKYLAB AUTOMATED SAMPLE PROCESSOR FOR PRESERVATION -70°C FREEZER FOR BLOOD -20°C FREEZER FOR URINE WILL ENABLE RETURN OF SAMPLES FOR TESTS SHOWN. DETERIORATION OF ELEMENTS SUCH AS PLASMA PROTEINS IN STORED SAMPLES CAN INVALIDATE DELAYED ANALYSES. REAL-TIME ANALYSIS CAPABILITY MAY BE REQUIRED FOR SOME OF TESTS SHOWN.
• <u>REAL TIME ANALYSIS OF:</u> BLOOD AND/OR URINE ELECTROLYTES K^+, Ma^+, Ca^{++}, Cl^- BLOOD PH BLOOD PCO_2 BLOOD PO_2	BLOOD & URINE SAMPLE ACQUISITION & ONBOARD ANALYSIS	ACCOMPLISHED WITH AUTOMATED POTENTIOMETRIC ELECTROLYTE ANALYZER UNDER DEVELOPMENT BY NASA (JSC).

of procedures and equipment developed in earlier periods of the present study provided a source of other procedures and hardware items to perform cardiovascular studies. Some Skylab research on cardiovascular functions required equipment such as a bicycle ergometer and a lower body negative pressure device, each of which is too large for use in the COLs. NASA provided information on a battery-operated ultrasonoscope that could be considered for use in the small COLs to measure cardiac output and heart size. Histological studies of myocardial tissue preparations from non-human test subjects could provide important data relative to myocardial degeneration resulting from zero-g exposures. Accordingly, this research option was included for consideration for implementation within a Category A laboratory, which will provide the capability for both biomedical and vertebrate research. Bioassays of body fluids and measurement of fluid compartment volumes and renal functions comprise a significant part of a research program in cardiovascular function analysis. These studies were thoroughly desccribed in the preceding section on body fluid composition and electrolyte functions. Cardiovascular function research options, requirements, and measurements considered for the COLs are shown in Table 4-4.

Table 4-4. Research Options and Requirements, Cardiovascular Functions

CARDIOVASCULAR RESEARCH OPTIONS	REQUIREMENTS/ MEASUREMENTS/EQUIPMENT	REMARKS
ECG	HARNESS, ELECTRODES SIGNAL CONDITIONER	CAN ALL BE PROVIDED IN CARRY-ON LABORATORY IF OPERATOR SKILL IS PROVIDED. ULTRASONOSCOPE CAN BE BATTERY OPERATED.
VCG	S/C INTERFACE	
BLOOD PRESSURE	SPHYGMOMANOMETER	
HEART SOUNDS	STETHESCOPE	
CIRCULATION	DOPPLER FLOW METER PHYSICAL EXAMINATION	
CARDIAC OUTPUT & DIMENSIONS	ULTRASONOSCOPE	
BODY TEMPERATURE	THERMOMETER	
EXERCISE TOLERANCE	BICYCLE ERGOMETER OR CALISTHENICS	BICYCLE ERGOMETER "EXPT. SPECIFIC" REGULATED EXERCISE CAN BE EMPLOYED
ORTHOSTATIC TOLERANCE	L.B.N.P.	L.B.N.P. "EXPERIMENT SPECIFIC"
MYOCARDIAL DEGENERATION	TISSUE BIOPSY	REQUIRES HUMAN SURROGATE
BLOOD & URINE CHEMISTRIES	BLOOD & URINE SAMPLE COLLECTION & RETURN	DESCRIBED UNDER BODY FLUID COMPOSITION & ELECTROLYTES.
BLOOD VOLUME		

4.2.2 BIOMEDICAL CATEGORY C COL CONCEPTS. Research options, requirements, and measurements defined for vestibular functions, body fluid composition, electrolyte functions, and cardiovascular functions (as presented in Tables 4-2, 4-3, and 4-4) were next used to define COL conceptual designs. The Category C COL designs are presented first with B and A following, for the reasons discussed previously in Section 4.1.2. The Category C COLs were limited to 23 kg (50 lb) and also were to fit into one or more 36 by 43 by 51 cm (14 by 17 by 20 inch) containers. If all high-priority research areas specified in the NASA guidelines could be met by use of four or fewer 50-pound COLs, they could all be satisfied by one Category B 91 kg (200 lb) COL, or a part of the Category A 227-318 kg (500-700 lb) COL. Keeping this in mind, fewer than four Category C COLs were sought to satisfy the high priority research requirements. As it turned out, they could be satisfied by the three Category C COLs which are described below. They are denoted as COLs C_1, C_2, and C_3.

All equipment items which make up each COL (including Categories A & B as well as C) are tabulated in the sections to follow. Each item is identified by an equipment item number (E.I.#) and all such items are described in more detail in Volume III entitled "Preliminary Equipment Item Specification Catalog".

4.2.2.1 Biomedical Category C COL Number One (C_1). Vestibular function research has many equipment requirements identical to those for body fluid composition and electrolyte function research. This commonality of equipment suggests economy in combining these two research areas in a single package. A 23 kg (50-lb) Category C COL (C_1) equipment list for accommodating real-time electrolyte studies and vestibular function research was defined as shown in Table 4-5. The major equipment item in this concept is the automated potentiometric electrolyte analyzer (APEA), which is currently undergoing development and testing at NASA/JSC. The analyzer will ultimately be capable of measuring blood pH, O_2, CO_2, Na^+, K^+, Cl^-, ionized Ca^{++}, total Ca, and glucose. It consists of bags of reagents, a fluid transport system, individual electrochemical modules for each electrolyte measurement, and associated electronics. These components can be packaged in various configurations. For the COLs, two modules were assumed with interconnecting electrical and fluid lines as shown in Figure 4-1. The figure shows two packages, 36 by 43 by 51 cm, which can be accommodated within the racks provided in the Shuttle Orbiter crew compartment. The remaining equipment items for this laboratory are packaged in a third 36 by 43 by 51 cm container shown in Figure 4-1. A detailed description of the containers and arrangement of this third module is shown in Figure 4-2.

4.2.2.2 Biomedical Category C COL Number Two (C_2). A second Category C COL (C_2) was conceived to perform body fluid composition and electrolyte functions research. This laboratory concept employs the blood sample processor centrifuge developed for Skylab and a -70°C freezer for preservation of blood and plasma for delayed ground analyses (Figure 4-3). Concept C_2 enables extensive ground analyses to complement and reinforce the inflight bioassay performed by Concept C_1. A tabulation of

Table 4-5. Biomedical COL C_1 Properties (Category C)

Mission Emphasis	- real time electrolyte studies and vestibular function. (Note: See Section 4.2.1.2 for discussion of application of equipment items for measuring body electrolytes to the study of vestibular disturbances.)
Constraints	- weight must not exceed 23 kg - laboratory must package into one or more 36×43×51 cm (14×17×20") modules
Crew	- requires trained technician to operate equipment and perform physical examinations

E.I.#	Equipment Item	Major Item Sizes cm	(in.)	Weight kg
C188	Automated Potentiometric Electrolyte Analyzer	36×43×51	(14×17×20)(2 reqd)	9.1
C210	Blood Acquisition Kit	20×25×25	(8×10×10)	1.4
C212	Urine Acquisition Kit	"	"	0.9
C211	Physical Examination Kit	"	"	2.0
C196	Equipment Restraints	3×20×20	(1×8×8)	0.5
C213	Waste Storage Bag	10×25×31	(4×10×12)	0.5
C116	Log Book			0.5
C203A	Oculogyral Illusion Box	10×10×10	(4×4×4)	0.2
C153	Voice Recorder			1.0
-	Structure			3.4
				19.5 (43 lb)

Research Measurements	Real-Time Analysis	Ground Analysis
Blood electrolytes - K^+, Na^+, Ca^{++}, Cl^-	×	
" pH	×	
" pCO_2	×	
" pO_2	×	
" hemoglobin	×	
" pressure	×	
" Doppler flow measurements	×	
" stained smears	×	
" differential counts		×
Urine electrolytes - K^+, Na^+, Ca^{++}, Cl^-	×	
" labstix chemistries	×	
" voided volume measurement	×	
Physical examinations	×	
Data acquisition & storage - log book, voice recorder	×	

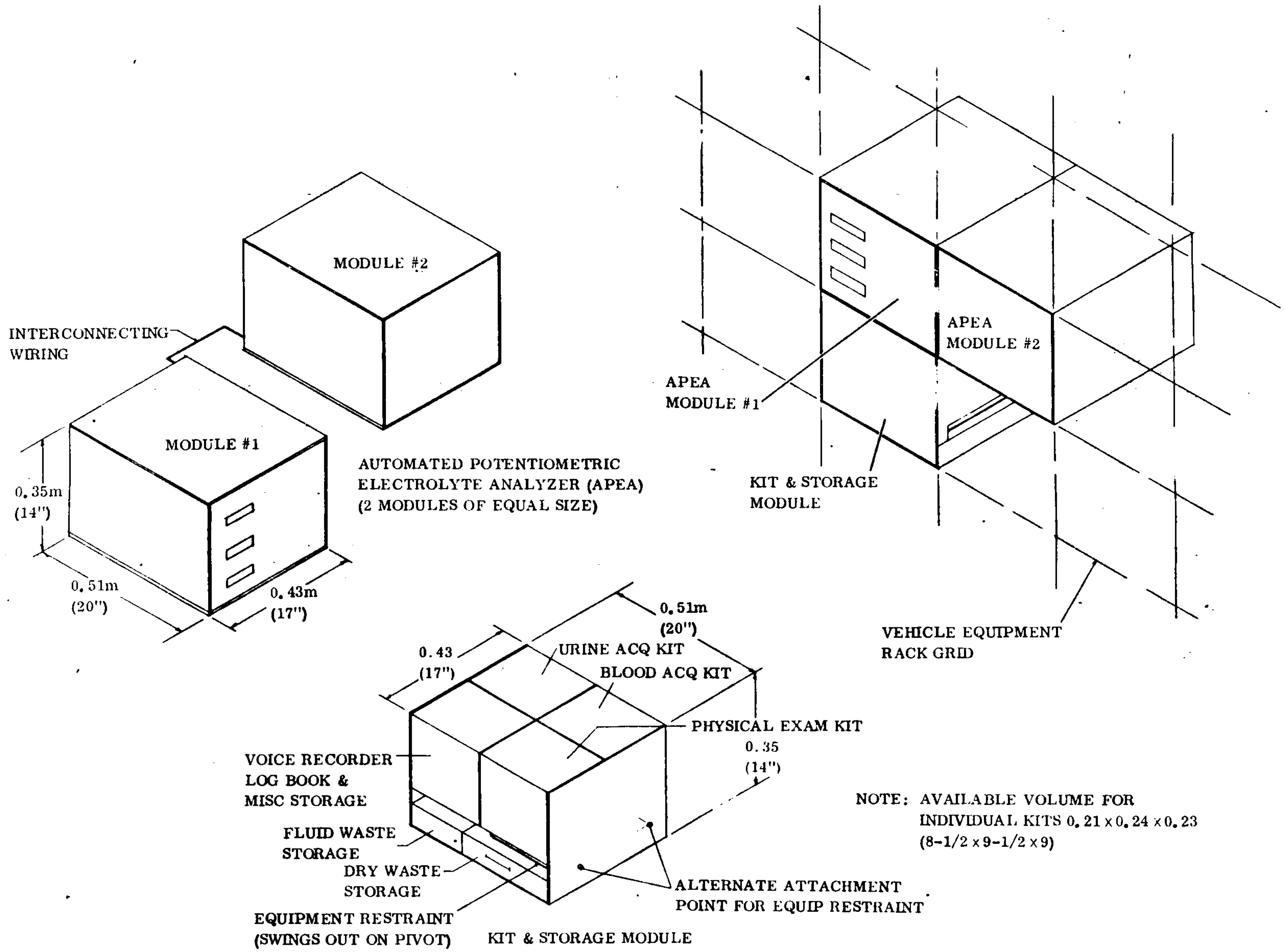


Figure 4-1. Biomedical COL C_1 Conceptual Installation Drawing

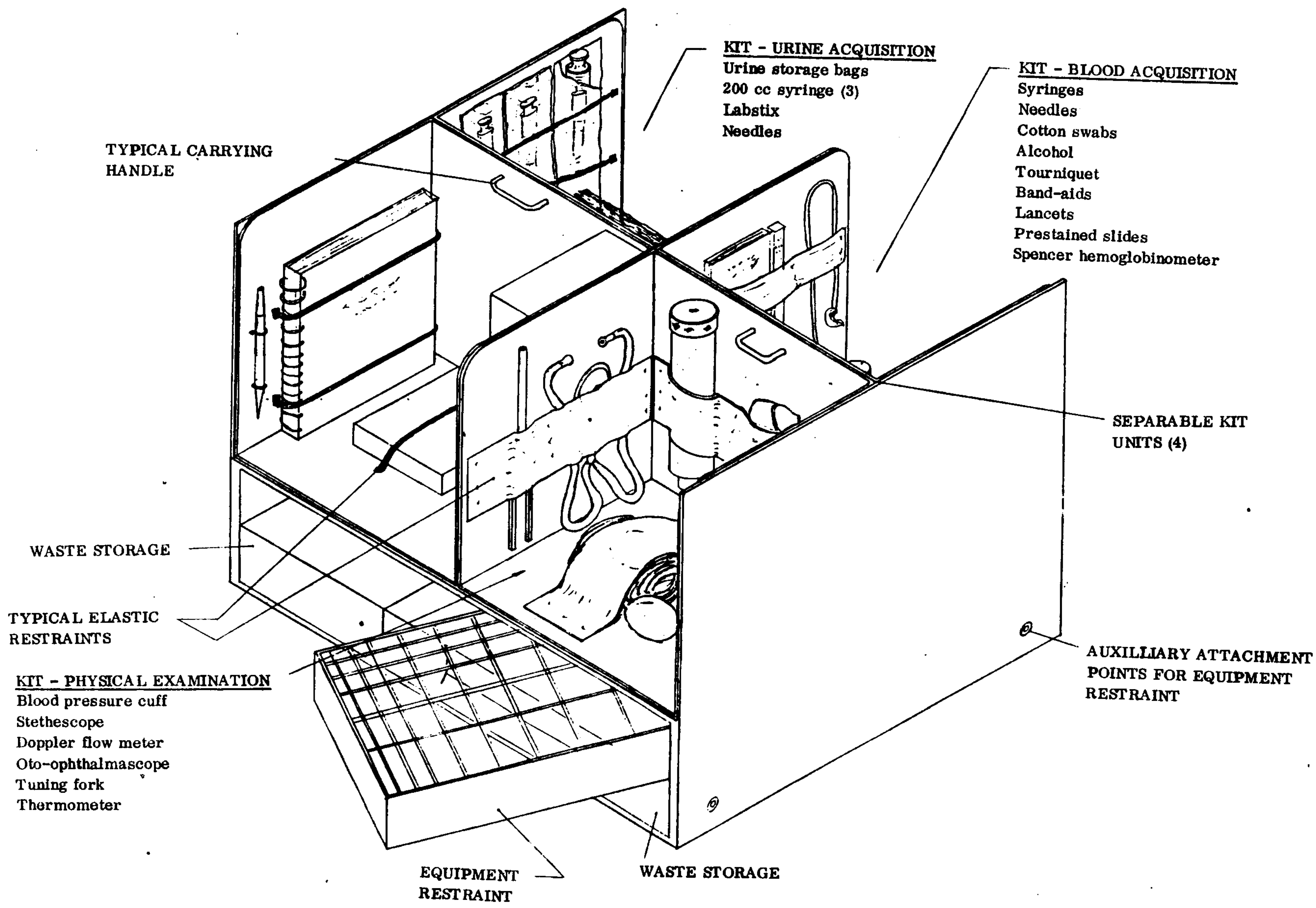


Figure 4-2. Biomedical COL C_1 Conceptual Design Sketch

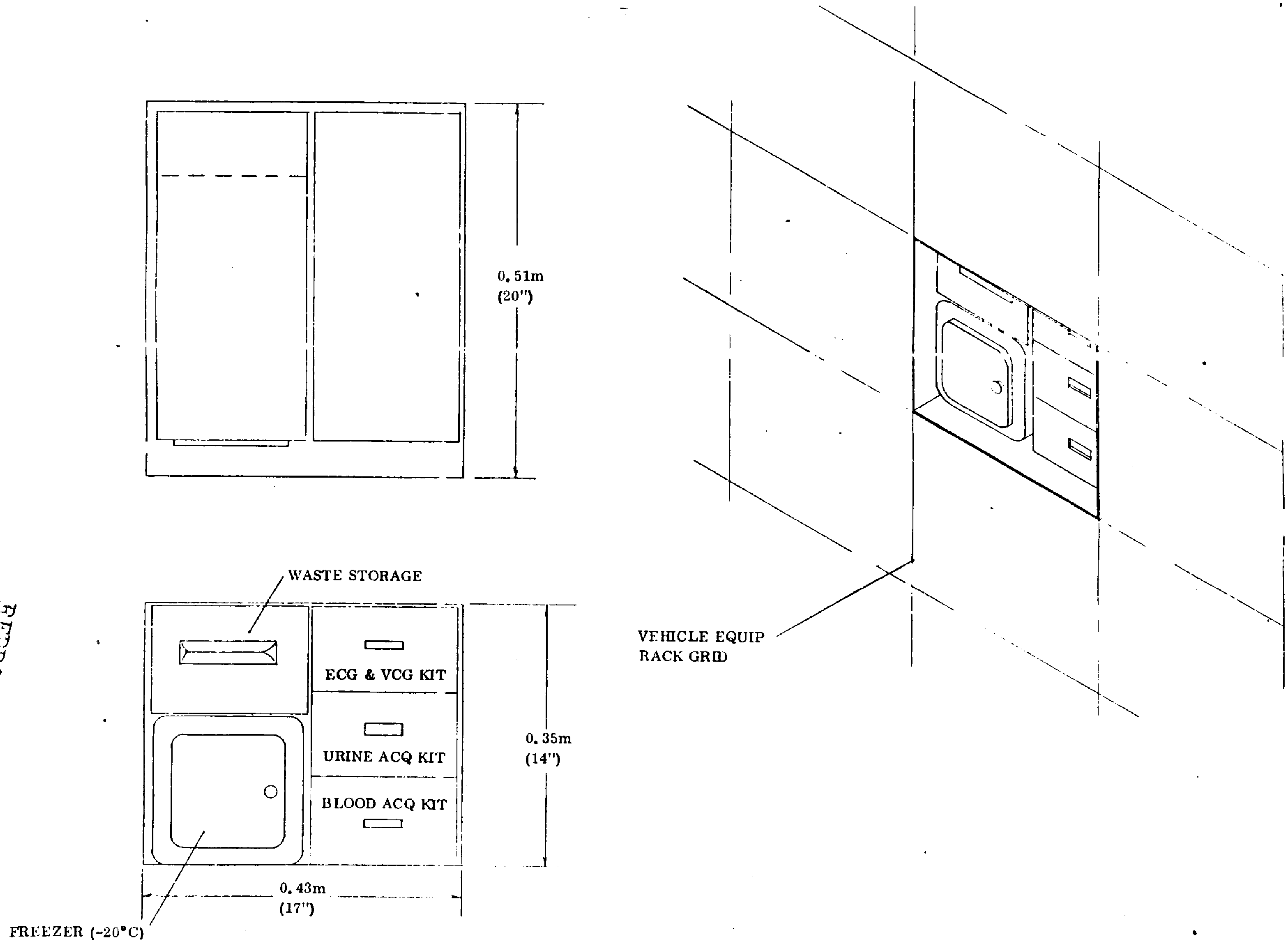


Figure 4-3. Biomedical COL C_2 Conceptual Design

equipment items, weights, and functional capability of Concept C_2 is provided in Table 4-6. Research on body fluid composition and electrolyte functions requires correlated analyses of blood and urine samples taken from the same subjects within the same time frame of zero-g exposure. Category C COL weight constraints preclude simultaneous collection and preservation of both blood and urine samples in this laboratory, so a third Category C laboratory was needed to provide the total capability for research specified by the NASA guidelines.

4.2.2.3 Biomedical Category C COL Number Three (C_3). This concept provides for urine collection and return for ground analysis to complement the blood collection and return capability provided by Concept C_2. Capability for cardiovascular and vestibular research is also provided in this laboratory concept, which is shown in Figure 4-4. As discussed earlier, space research of vestibular disturbance, cardiovascular adaptation, and body fluids/electrolyte and renal function adaptations to weightlessness are all interrelated and ideally should be studied simultaneously in the same subjects during the same mission and time frame. Accordingly, Concepts C_2 and C_3 should be flown together to accomplish such research objectives if the combined weight of 42 kg can be accommodated in the spacecraft. The equipment items, weights, volume, and functional capability contained in Concept C_3 are shown in Table 4-7. This laboratory can be packaged in one 36 by 43 by 51 cm (14 by 17 by 20 inch) container. Table 4-8 summarizes the seven possible Category C COL combinations provided by these three concepts.

4.2.3 BIOMEDICAL CATEGORY B COL CONCEPTS. The Group 1 NASA research priorities for the Category B laboratory included vestibular, body fluid, electrolyte, and cardiovascular functions research in the identical priority as required for the Category C COLs (Section 4.1). Accordingly, the inventory of equipment selected for the Category C laboratories and described in the preceding sections can also be used in the larger 91 kg Category B concept.

The Group 2 research priorities for the Category B laboratory included hemodynamic, blood morphology and blood chemistry functions research. The blood sample processor centrifuge and the -70°C freezer employed in Concept C_2 will return sufficient plasma and blood sample material to encompass all blood-function research required for both Group 1 and Group 2 research in the Category B guidelines. The -20°C freezer required for preservation and return of urine samples for delayed ground analysis can also be provided within the 91 kg weight constraint on this laboratory.

The total inventory of equipment selected for the Category B COL is shown in Table 4-9. Each item in this list is identified by an EI number and all such items are described in more detail in Volume III, "Preliminary Equipment Items Specification Catalog. The Category B COL includes all equipment items contained in the three Category C laboratories, except for the automated potentiometric electrolyte analyzer. As discussed

Table 4-6. Biomedical COL C_2 Properties (Category C)

Mission Emphasis	- Blood fluid composition & electrolyte functions
Constraints	- Weight must not exceed 23 kg - Must package into one or more 36×43×51 cm (14×17×20 in.) modules
Crew	- Requires trained technician

E.I. #	Equipment Item	Sizes cm	Sizes (in.)	Weight kg
C189	Blood Sample Processor Centrifuge (Preservation)	30×36×36	(12×14×14)	12.7
C210	Blood Acquisition Kit			1.4
C81	Freezer (-70°C, 1 liter capacity)	20×20×36	(8×8×14)	7.0
-	Structure			1.8
		(Package all but freezer in one 36×43×51 cm container)		
	Total			22.9 (50 lb)

Research Measurements		Ground Analysis
Plasma Electrolytes	per Skylab M071	×
Plasma Proteins	" " M112	×
Plasma Angiotensin I Aldosterone Osmolality	per Skylab M073	×
RBC Mass & Life Span	" " M113	×
Blood Enzymes	" " M114	×
Hemoglobin Blood Hematocrit Cellular Potassium	per Skylab M115	×
Blood Stained Smears		×
Blood Differential Counts		×

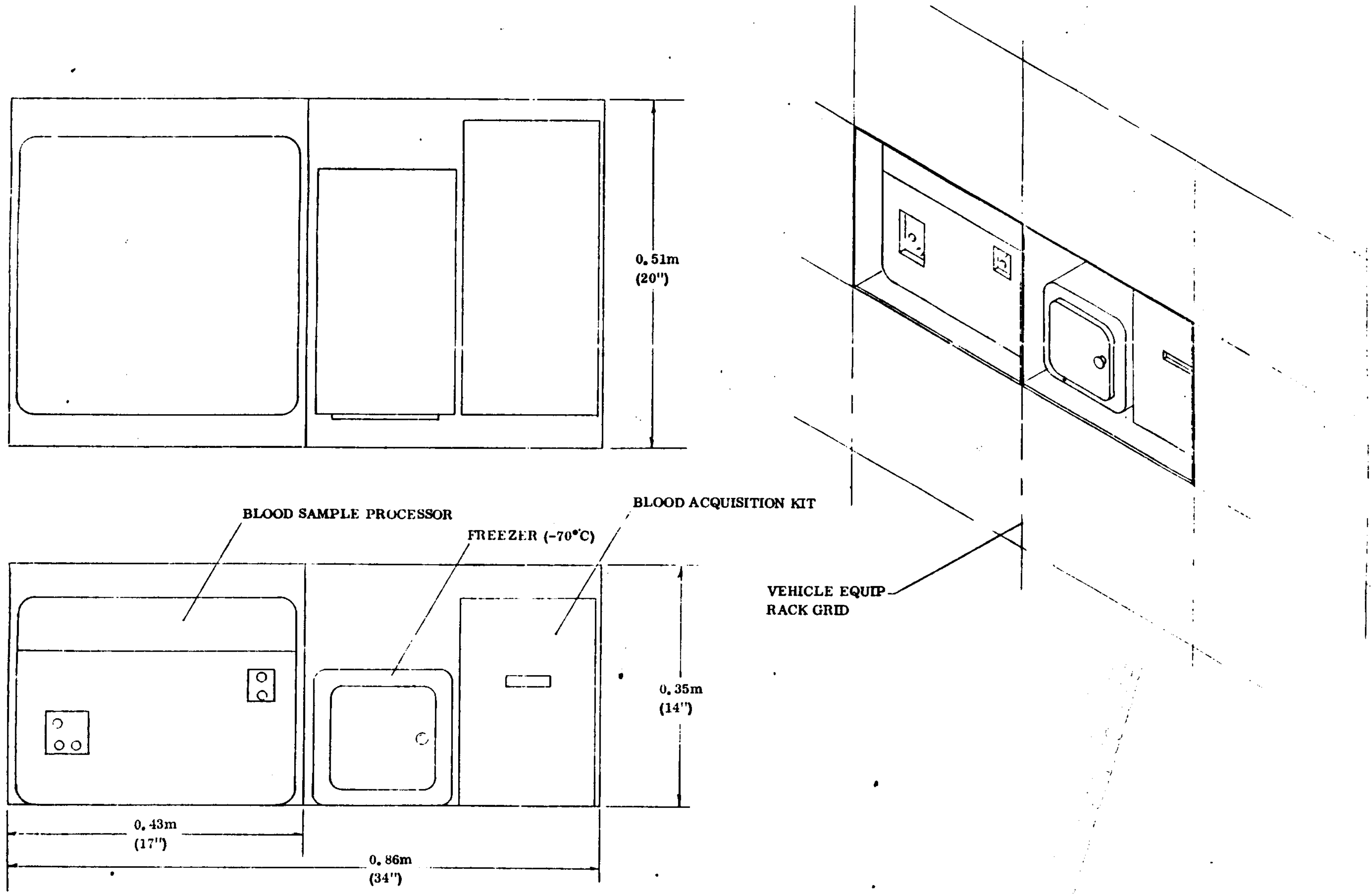


Figure 4-4. Biomedical COL C_3 Conceptual Design

Table 4-7. Biomedical COL C_3 Properties (Category C)

MISSION EMPHASIS - URINE COMPOSITION, CARDIOVASCULAR FUNCTIONS, VESTIBULAR FUNCTIONS*

CONSTRAINTS
- WEIGHT MUST NOT EXCEED 23 KG
- MUST PACKAGE INTO ONE OR MORE 36×43×51 CM (14×17×20 INCH) MODULES

E.I. #	EQUIPMENT ITEM	MAJOR ITEM SIZES cm (in.)	WEIGHT kg
C80	FREEZER (-20°C - 6 LITER CAPACITY)	20×20×36 (8×8×14)	7.0
C211	PHYSICAL EXAMINATION KIT		1.4
C156	COUPLERS (8)		1.2
C208	WIRE & CABLE		2.0
C203A	OCULOGYRAL ILLUSION BOX		0.2
C212	URINE ACQUISITION KIT		0.9
C149G	RADIOISOTOPE TRACERS		0.3
C210	BLOOD ACQUISITION KIT		1.4
C116	LOG BOOK		0.5
C213	WASTE STORAGE BAGS		0.5
-	STRUCTURE		3.6
	TOTAL (PACKAGED IN ONE 36×43×51 CM MODULE)		19.0 (42 LB)

RESEARCH CAPABILITY		ANALYSIS	
		REAL TIME	GROUND
URINE VOIDED VOLUME	M073	X	
URINE COMPOSITION & CHEMISTRIES	M073	X (LABSTIX)	X
BODY FLUID COMPARTMENT VOLUMES	M073		X
VECTOR CARDIOGRAPHY			X
PHYSICAL EXAMINATION		X	
STAINED SMEARS		X	
DIFFERENTIAL BLOOD COUNTS			X
DOPPLER BLOOD FLOW MEASUREMENTS		X	
BLOOD HEMOGLOBIN		X	
DATA ACQUISITION & STORAGE - LOG BOOK		X	

*Application of equipment items for measuring urine composition and cardiovascular functions to study vestibular disturbances is discussed in Section 4.2.1.1.

Table 4-8. Biomedical Category C COL Combinations

CATEGORY C CONCEPT	WEIGHT KG	POWER W	NUMBER OF MODULES 36×43×51 CM	RESEARCH MISSION EMPHASIS					
				VESTIBULAR FUNCTIONS	BODY FLUID & ELECTROLYTE FUNCTION				CARDIO-VASCULAR FUNCTIONS
					BLOOD		URINE		
					FLIGHT	GND	FLIGHT	GND	
COL_1	19.5	25	3	X	X		X		
COL_2	22.9	425	2			X			
COL_3	19.0	41	1	X				X	X
$COL_1 + COL_2$	42.4	450	5	X	X	X	X		
$COL_1 + COL_3$	38.5	66	4	X	X		X	X	X
$COL_2 + COL_3$	41.9	466	3	X		X		X	X
$COL_1 + COL_2 + COL_3$	61.4	491	6	X	X	X	X	X	X

Table 4-9. Biomedical COL Equipment Items and Properties (Category B)

E.I. NOS.	RESEARCH EQUIPMENT ITEMS (E.I.'S)	WEIGHT FOR 7-DAY MISSION, kg	VOLUME, dm^3	POWER, watts
C85	BLOOD GAS ANALYZER	8.2	45.3	55
C189	BLOOD SAMPLE PROCESSOR CENTRIFUGE (PRESERVATION)	12.7	25	100
C34	*CAMERA, 35 MM	2	2	0
C156	COUPLERS (6 INCLUDED)	1.2	3	12
C55B	*CREW RESTRAINTS	4	10	0
C192	*DISPLAY, NUMERIC	2	4	2
C196	EQUIPMENT RESTRAINTS	0.5	1	0
C80	FREEZER, GENERAL	7	15	50
C81	FREEZER, LOW TEMPERATURE	7	15	400
C106	KIT, HEMATOLOGY	4	6	0
C110C	KIT, HUMAN PHYSIOLOGY	3	8	0
C116	LOG BOOKS	0.5	0.4	0
C132	*OSCILLOSCOPE (BATTERY)	1.6	2.4	0
C149G	RADIOISOTOPE TRACERS	0.3	0.5	0
C153	RECORDER, VOICE (BATTERY)	1	0.4	0
C83	*REFRIGERATOR	5	17	15
C180	*TIMER, EVENT	0.2	0.2	0
C181G	WASTE STORAGE CONTAINER (SMALL SIZED)	0.5	14	0
C208	WIRE AND CABLE	2	4	0
C209	*WORK SURFACE, AIRFLOW	5	6	75
	RESEARCH EQUIPMENT TOTALS	67.7 (149 LB)	179.2 ($6.33\ FT^3$)	709
	PLUS THE WEIGHT OF:			
	*RESEARCH EQUIPMENT MODULE	17		0
	TOTALS	84.7 (187 LB)	SEE DRWG.	709

*NOT INCLUDED IN CATEGORY C LABS.

previously in Section 4.1.2, however, a blood gas analyzer was provided to enable inflight blood gas measurements. This laboratory also contains a camera, crew restraints, numeric displays, oscilloscope, refrigerator, timer, work surface, and research equipment console, which were not included in any of the Category C laboratories. The hematology and human physiology kits are also items which were not included in the Category C laboratories but many of the items within these kits were included in the Category C COLs. However, they were packaged in the smaller, more limited blood acquisition kit, urine acquisition kit, and physical examination kit as explained in Section 4.1.2. The Category B concept provides sufficient flexibility to enable substituting the automated potentiometric electrolyze analyzer for the blood gas analyzer and some other equipment item of 3 kg (7 lb) or more weight. Accordingly, if maximum capability for inflight analyses is desired, this equipment interchange can be accomplished within the 200-pound total weight constraint.

The lower body negative pressure device used in Skylab cardiovascular studies was precluded from this laboratory because of the weight and volume limitations. Likewise, the rotating litter chair used in Skylab experiments for study of vestibular functions exceeded the weight and volume constraints for the Category B COL. To preserve the capability to exercise these omitted items, couplers are provided in the Category B COL so that studies using the LBNP or rotating chair devices could be accomplished if these items were provided as experiment-specific equipment. The cardiovascular studies included in the Category B COL will emphasize vectorcardiogram, Doppler flow meter, and blood pressure measurements. The Category B laboratory is shown in Figure 4-5; a detailed description of this laboratory and the packaging arrangement is shown in Figure 4-6.

4.2.4 BIOMEDICINE/BIOLOGY CATEGORY A COL CONCEPTS

4.2.4.1 COL For Biomedical and Small Vertegrate Research. The allowable weight range of 227 to 318 kg (500 to 700 lb) for the Category A laboratory enables inclusion of all biomedical equipment items employed in the Category B and C COLs, plus other equipment for both biomedical and small vertebrate research. The equipment list for this laboratory is shown in Table 4-10. All items are described in more detail in Volume III. Equipment items were selected to encompass all research capabilities requested in the NASA guidelines, with greatest emphasis placed on those given highest priority. The holding unit, cages, ventilation unit, dissection boards, dissection and high-powered microscopes, and kits for specimen, acquisition, preparation, and storage comprise one major difference between the Category A laboratory and the smaller COLs. This laboratory is equippped with both the blood sample processor centrifuge for delayed ground analysis of blood chemistires and the automated potentiometric electrolyte analyzer for inflight analysis of blood and urine chemistires. The sample processor centrifuge is designed to accept spring-loaded syringes containing 11 ml blood samples for biomedical analysis. Blood samples for small animal

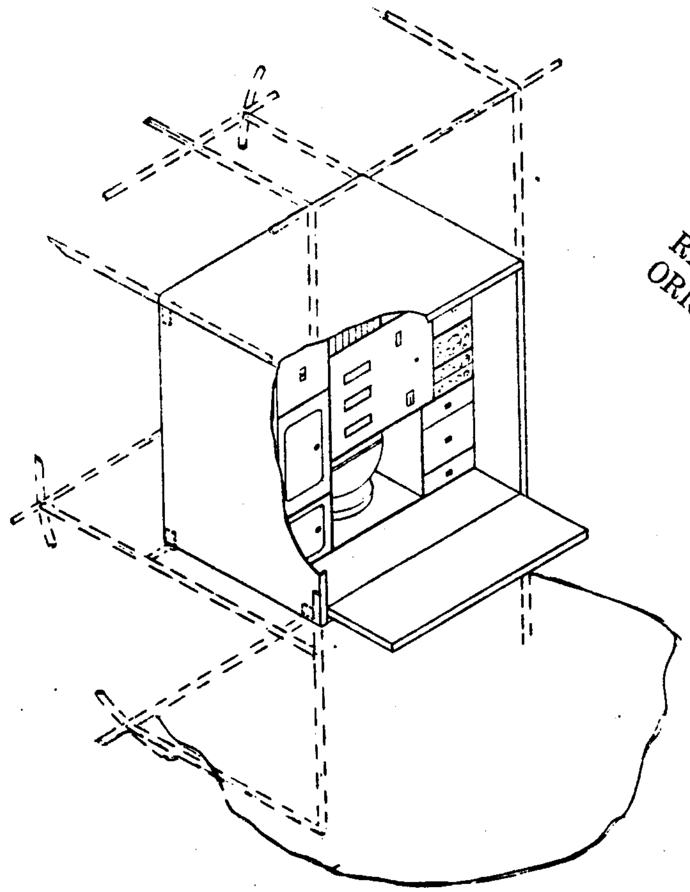


Figure 4-5. Category B Biomedical COL Conceptual Installation Drawing

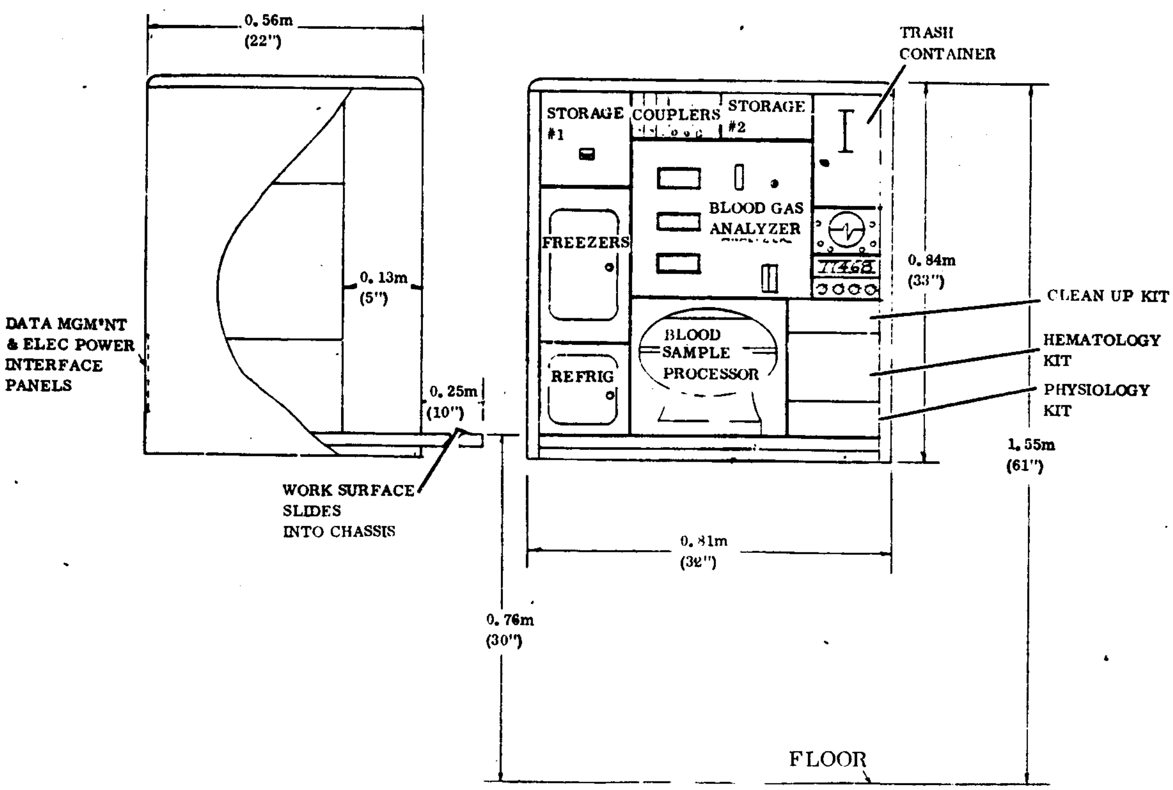


Figure 4-6. Category B Biomedical COL Conceptual Design Drawing

Table 4-10. Category A Biomedicine/Biology COL Equipment Items and Weight, Volume, and Power

E.I. NO.	EQUIPMENT ITEMS (E.I.'S)	WEIGHT FOR 7-DAY MISSION, KG	VOLUME, DM^3	POWER, WATTS
C6	*AIR PARTICLE SAMPLER	2.6	0.9	50
C188	AUTO. POTEN. ELECTROLYTE ANALYZER	9.1	131	100
C189	BLOOD SAMPLE PROCESSOR CENTRIFUGE	12.7	25	100
C30A	*CAGE, SMALL VERTEBRATES (8 INCL.)	18.4	88	72
C38	*CAMERA, VIDEO, COLOR	7.7	6.2	69
C34	CAMERA, 35MM	2	2	0
C156	COUPLERS (12 INCL.)	2.4	6	24
C55A	*CREW MOBILITY AIDS	2.3	2.8	0
C55B	CREW RESTRAINTS	4	10	0
C192	DISPLAY, NUMERIC	2	4	2
C167B	DRY STORAGE CONTAINER (ROOM TEMP)	0.5	3	0
C196	EQUIPMENT RESTRAINTS	0.5	1	0
C80	FREEZER, GENERAL	7	15	50
C81	FREEZER, LOW TEMPERATURE	7	15	400
C103	*HOLDING UNIT, SM. VERT.	13.6	188	0
C198	*INCUBATOR, 37C (MINI)	5	8	5
C200	*KIT, ANIMAL PHYSIOLOGY	1.5	2	0
C106A	*KIT, CLEAN-UP	1.5	5	0
C113	*KIT, GENERAL TOOL	4.5	14.2	50
C106	KIT, HEMATOLOGY	4	6	0
C108	*KIT, HISTOLOGY	1	1	0
C110C	KIT, HUMAN PHYSIOLOGY	3	8	0
C110	*KIT, MICROBIOLOGY	2	3	0
C114A	*KIT, MICRODISSECTION	1	2	0
C110B	*KIT, VERTEBRATE MANAGEMENT	3	6	0
C202	*LAMP, PORTABLE HI INT. PHOTO	6.3	6	150
C116	LOG BOOKS	0.5	0.4	0
C91	*MASS SPECTROMETER	11.3	16.4	30
C126	*MICROSCOPE, COMPD	11	28	50
C126A	*MICROSCOPE, DISSECTING	9	28	63
C203A	OCULOGYRAL ILLUSION BOX	0.2	1	0
C132	OSCILLOSCOPE (BATTERY POWERED)	1.6	2.4	0
C149G	RADIOISOTOPE TRACERS	0.3	0.5	0
C153	RECORDER, VOICE (BATTERY POWERED)	1	0.4	0
C83	REFRIGERATOR	5	17	15
C153B	*SENSORS, MISCELLANEOUS	2	2	4
C206	*SHROUD, DEBRIS CONTAINMENT	4.5	300 (depl.)	0
C165	*STERILIZER, TOOL (BACTECINERATOR)	1	1	110
C177	TEMPERATURE PROBES	0.3	0.4	0
C180	TIMER, EVENT	0.2	0.2	0
C48	*VACUUM CLEANER	2.3	10	100
C193	*VENTILATION UNIT, SMALL VERT.	9.5	19	40
C181G	WASTE STORAGE CONTAINER	1	28.3	0
C174	*WATER TANK, ORGANISM (WET WT.)	4.6	22	0
C208	WIRE AND CABLE	2	4	0
C209	WORK SURFACE, AIRFLOW	5	6	75
	RESEARCH EQUIPMENT TOTALS	196.9 (434 LB)	1046.1 (36.94 FT^3)	1559
	PLUS THE WEIGHT OF: RESEARCH EQUIPMENT MODULES	64		0
	TOTALS	260.9 (575 LB)	SEE DRAWING	1559

*E.I.'S NOT INCLUDED IN CATEGORY B & C BIOMEDICAL COL'S.

studies will, of necessity, be limited to much smaller volumes. Consequently, the design concept provides for an adapter to be inserted in the receiver of the centrifuge that will enable small-animal blood samples to be spun down with this device.

This Category A laboratory contains couplers to enable electrophysiological monitoring, onboard displays, and downlink transmission of biomonitoring signals from crew or animal subjects. These couplers provide the interfaces for experiment-specific equipment items that could be flown in conjunction with a Category A laboratory mission. The selected Category A laboratory configuration is illustrated in Figure 4-7.

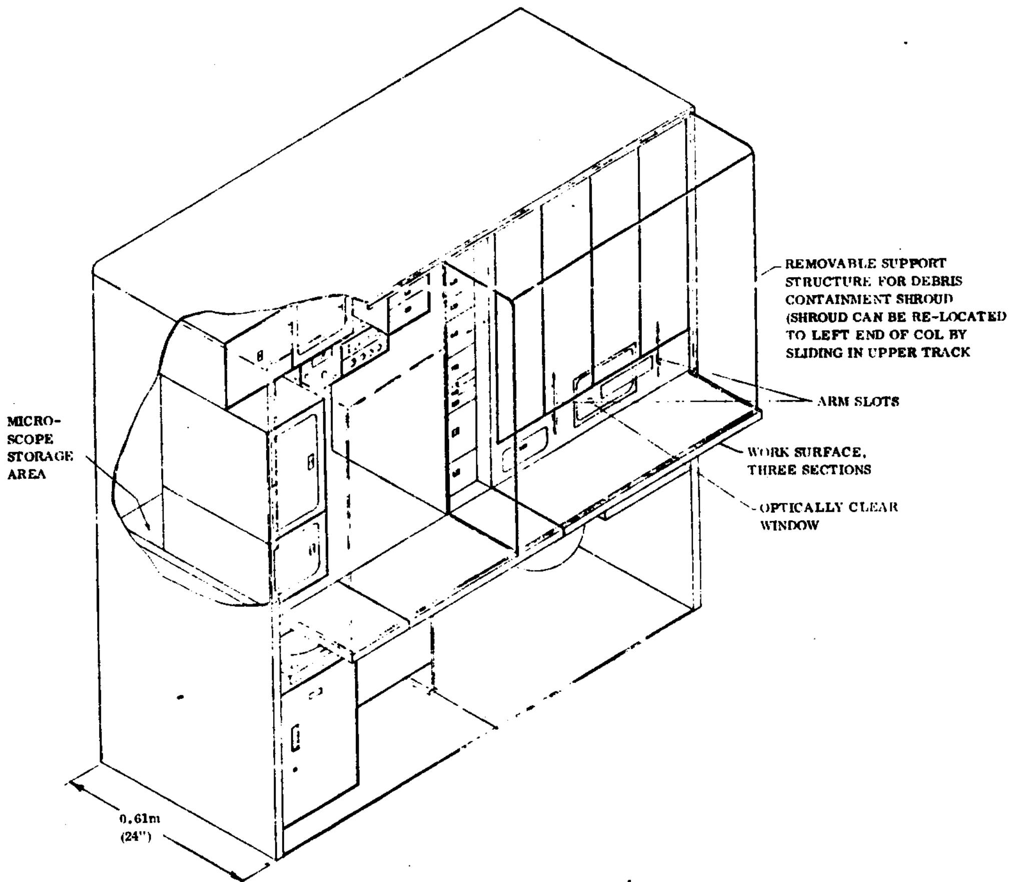


Figure 4-7. Category A Biomedicine/Biology COL

Air supplied to the vertebrate holding unit is ambient crew compartment air, filtered of particulates and then passed through the holding unit to ensure that experimental animals are exposed to the same gaseous environment as the crew. Effluent air from the holding unit is filtered to remove odor and particulate material prior to being returned to the crew compartment. A transparent, flexible shroud for debris containment is provided in this design concept. The shroud is equipped with arm slits to enable the experimenter to gain access to all equipment within the shroud. With the shroud positioned over the area in front of the vertebrate holding unit, all other equipment items required for vertebrate handling procedures are located within the shroud. When doors to the holding unit are opened, this debris shroud prevents escape of unfiltered effluent air, animal wastes, etc. into the crew compartment. An optical window is inserted in the shroud to provide optimum viewing of experimental procedures when required. When the vertebrate holding unit doors are closed, this debris shroud can slide to a position in front of the biomedical equipment console area, if desired, to prevent escape of research materials into the crew compartment while performing biomedical research procedures.

Equipment locations console dimensions and component details are shown in Figures 4-8 and 4-9. Dimensions of the modules of this Category A laboratory were selected to ensure that any of the modules can be passed through a 102-cm (40-inch)-diameter hatch when the work bench is retracted. The concept enables the vertebrate facilities such as the holding unit, the ventilation blower and filter, and the kits to be removed with minimum impact on the remaining modules. This enables easy conversion of the laboratory for simultaneous biomedical and animal research into a laboratory for performing only biomedical research missions. The concept also would allow the removal of the vertebrate holding unit and substitution of other support equipment to conduct research in the other life sciences FPEs, (e.g., cells and tissues, plants, and invertebrates). In this manner, the Category A laboratory concept emphasizes multiple mission use of a few basic COL modules to encompass a broad range of space life sciences research. This laboratory, in conjunction with Category B and C COLs, will provide a variety of laboratories with weights ranging from a single 23 kg (50 pound) Category C COL to a semi-dedicated laboratory comprised of any desired aggregate of these COL modules.

4.2.4.2 <u>COL for Biomedical, Small Vertebrate, and Cells/Tissues Research</u>. The basic Category A biomedicine/biology COL concept studied was described in Section 4.2.4.1. This basic concept supports both biomedical and small vertebrate research. Following its definition, however, the question arose as to what differences would result if the capability to support cells and tissues research were added to this basic COL. The majority of equipment needed for cells and tissues research is already included for biomedical and vertebrate research, so relatively minor additions will add the capability for cells and tissues research. The major additional items (cells/tissues holding unit, a colony counter, and pH meter) are shown in Figure 4-10 and listed in Table 4-11.

4.2.5 <u>BIOMEDICINE/BIOLOGY CATEGORY A COL BREADBOARD DESIGN</u>. Currently, NASA has an ongoing test program at MSFC for many of the proposed Spacelab payload concepts. This is the Concept Verification Test (CVT) program, in which a hard mockup similar to the Spacelab is used to house and evaluate payload equipment such as the Life Sciences COLs. In conjunction with this program, one of the final COL concepts was selected by NASA for detailed breadboard design. The COL selected was the Category A COL for biomedical and small vertebrate research described in Section 4.2.4.1.

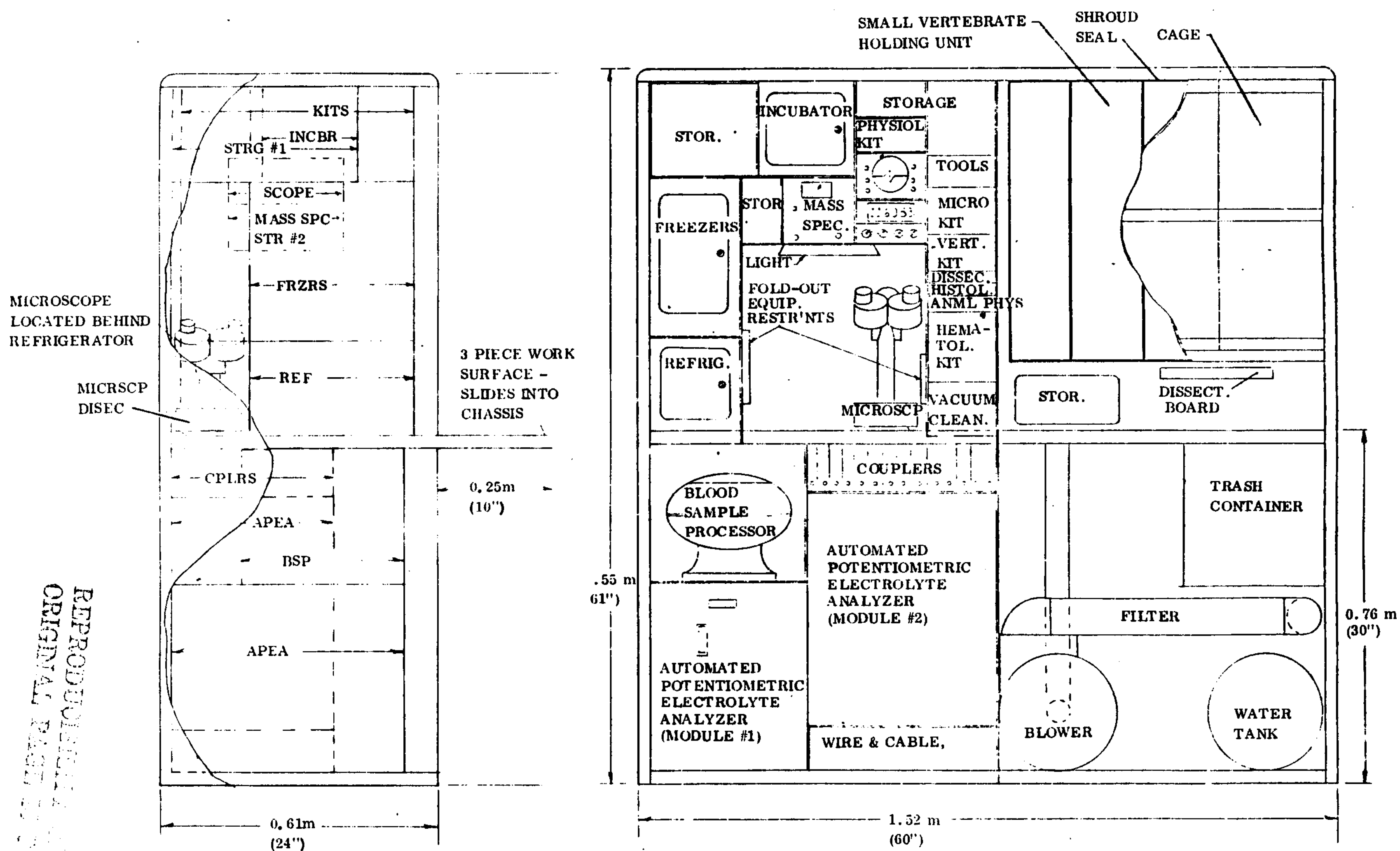


Figure 4-8. Category A Biomedicine/Biology COL Conceptual Design Drawing

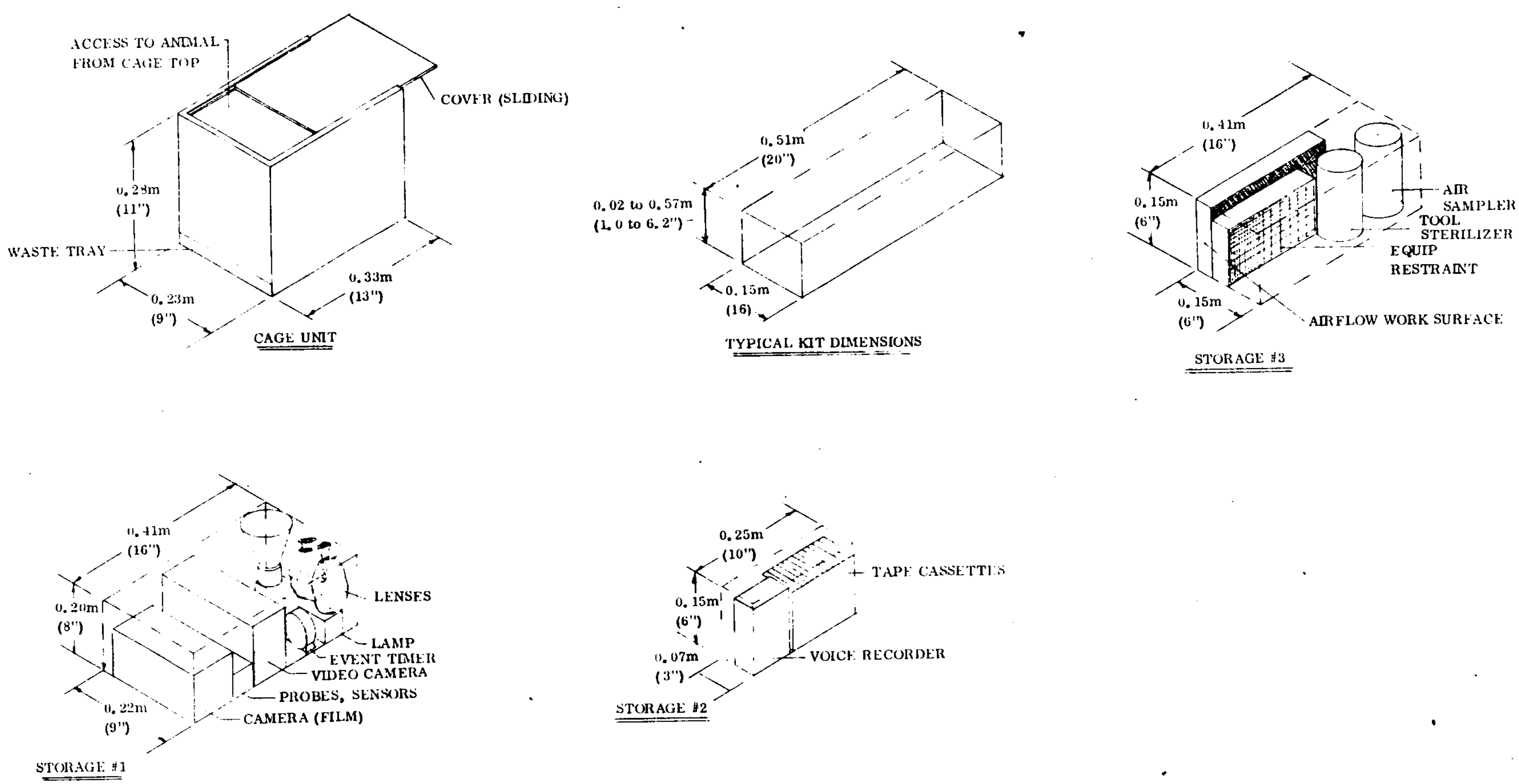


Figure 4-9. Category A Biomedicine/Biology COL Component Conceptual Designs

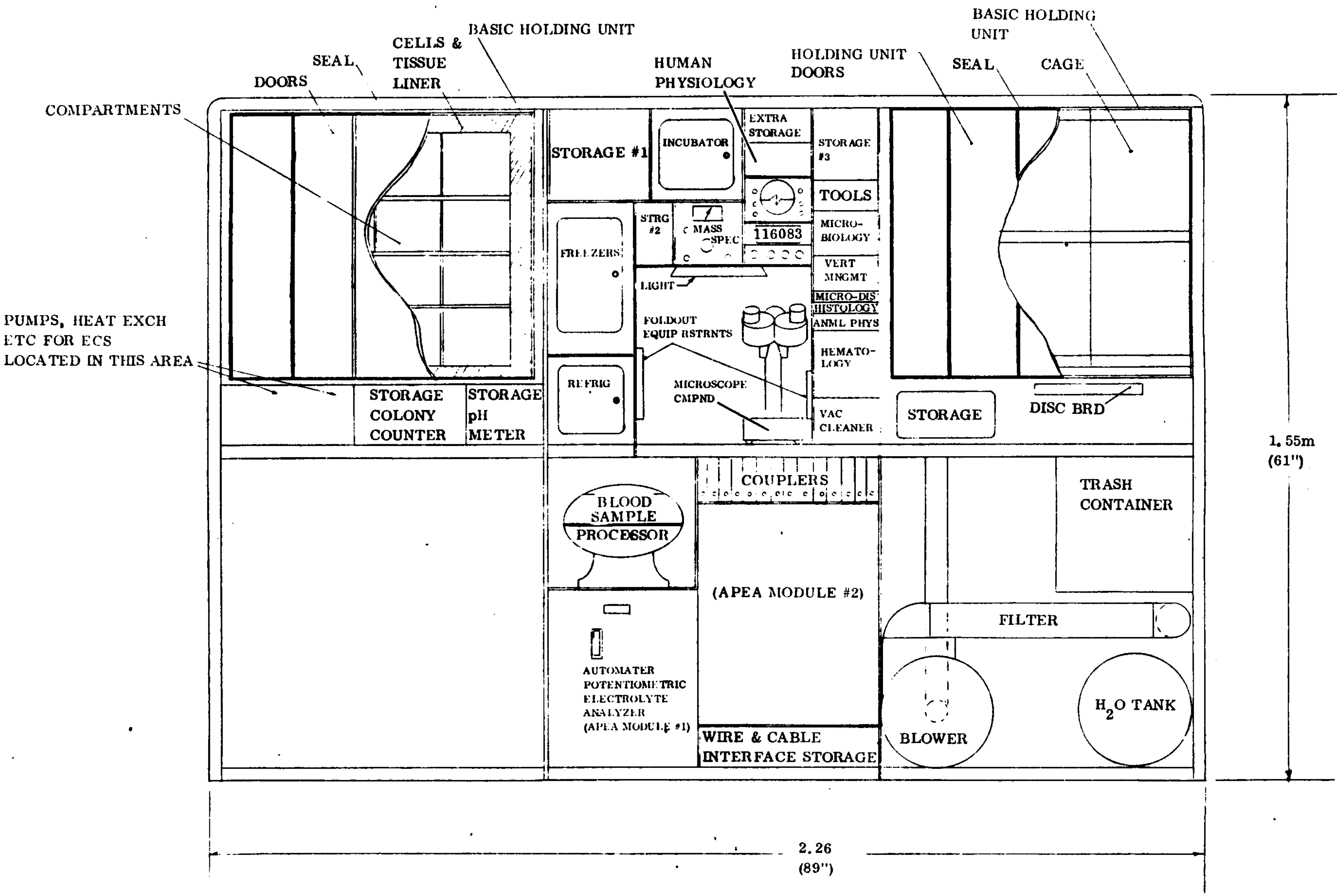


Table 4-10. Category A Biomedicine/Biology COL Design Concept for Biomedical, Small Vertebrate, and Cells and Tissues Research

Table 4-11. Characteristics of a Biomedicine/Biology COL for Biomedical, Small Vertebrate, and Cells and Tissues Research

CHARACTERISTIC	BASIC CONCEPT	ADDED REQ'MTS FOR C&T RESEARCH	TOTAL
WEIGHT, KG (LBS)	261 (575)	58 (127)	337 (741)
POWER - WATTS			
PEAK	1099	100	1199
AVERAGE	756	53	809
WATT-HRS/DAY	6807	1207	8041
ENVELOPE VOLUME, DM^3 (FT^3)	1440 (51)	480 (17)	1920 (68)
ADDED EQUIPMENT	NOT APPLICABLE	HOLDING UNIT COLONY COUNTER pH METER	

4.2.5.1 Guidelines. The guidelines required that breadboard design drawings be prepared to permit fabrication and assembly of the biomedicine/biology COL. To minimize costs, maximum use of commercial off-the-shelf and government furnished equipment (GFE) was to be specified. The GFE was to include, where applicable, equipment used in previous Life Sciences CVT activity, as well as other NASA sources.

4.2.5.2 Design. The breadboard design is similar in appearance to that described in Section 4.2.4.1, with the major difference in the configuration of the refrigerator and freezers. In the breadboard design, these items are of standard laboratory size and performance. The flight versions are considerably smaller and have a lower temperature capability (-70°C).

The breadboard is composed of three modules, as shown in Figure 4-11. Module 1 contains the common holding unit, Module 2 contains most of the diagnostic equipment, and Module 3 includes the refrigerator/freezer, mass spectrometer, and incubator. The design permits biomedical research activity using only Modules 2 and 3. The addition of Module 1 provides the vertebrate surrogate capability or basic biology research capability. Table 4-12 is the parts list for the breadboard. The list contains all equipment items required to fabricate and assemble the breadboard.

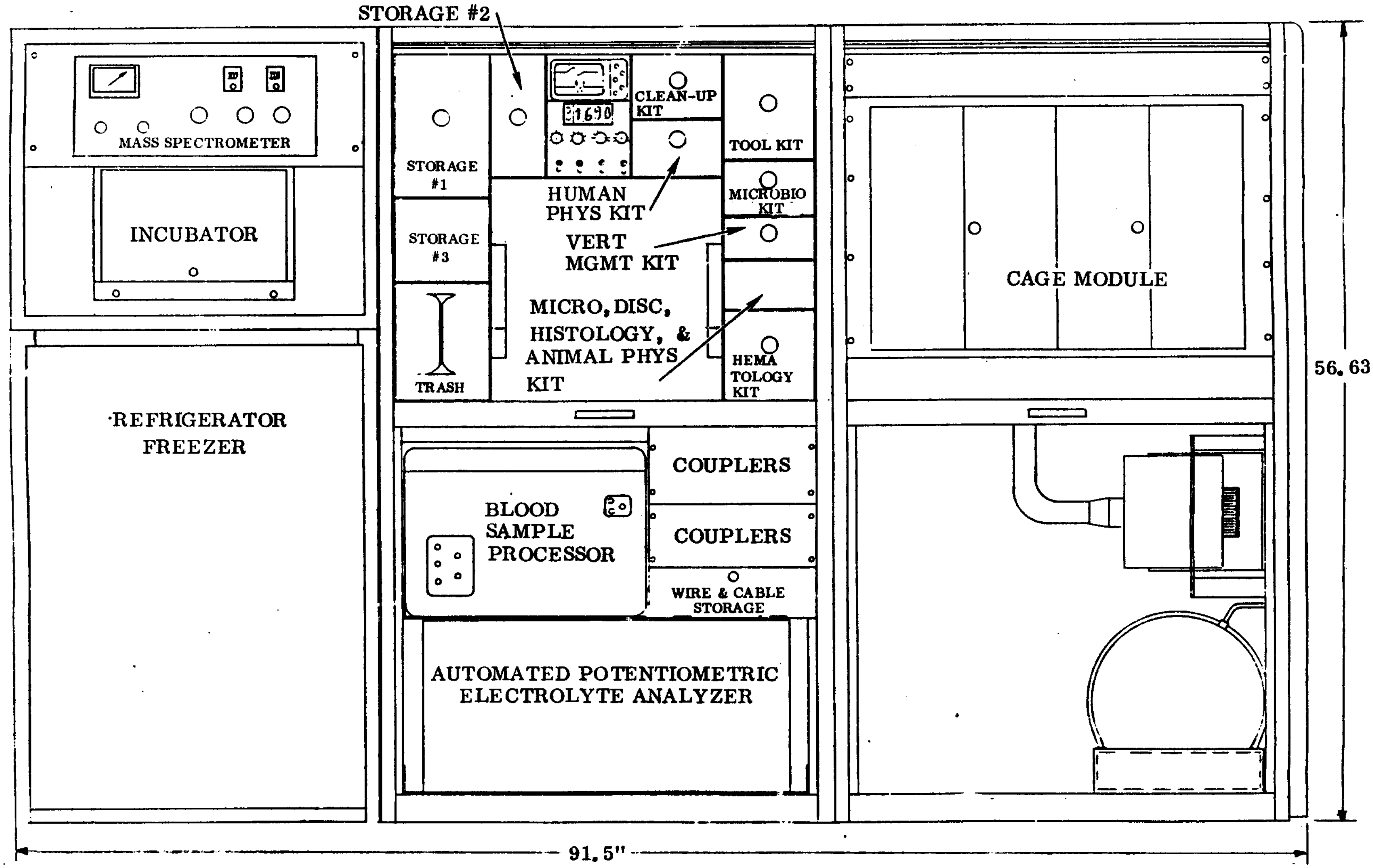


Figure 4-11. Biomedical/Biology Breadboard Assembly Drawing

Table 4-12. Breadboard Parts List

USED IN MODULES 1	2	3	NO. REQ.	PART NUMBER	DESCRIPTION	NOTES - SOURCE - SIZE - MATERIAL
	X		12		Couplers	Make - Purchase & Assembly
	X		1		Kit, Vert Mgmnt	Make - Purchase & Assembly
	X		1		Kit, Microdissection	Make - Purchase & Assembly
	X		1		Kit, Microbiology	Make - Purchase & Assembly
	X		1		Kit, Human Phys	Make - Purchase & Assembly
	X		1		Kit, Histology	Make - Purchase & Assembly
	X		1		Kit, Hematology	Make - Purchase & Assembly
	X		1		Kit, Tool	Make - Purchase & Assembly
	X		1		Kit, Clean Up	Make - Purchase & Assembly
	X		1		Kit, Animal Phys	Make - Purchase & Assembly
	X		1		Lamp, Photo	Buy Commercial
	X		1	Cat. No. 4H531	Vacuum Cleaner	Grainger-Eureka
	X		1		Camera, 35 mm	GFE - from MSFC
	X		1		Camera, Video	GFE - Skylab Unit
	X		6		Cassette Tapes	Buy Commercial
	X		1	Model 2605	Cassette Recorder	Craig Corporation
	X		1	Cat. No. 62348-000	Event Timer	VWR Scientific
	X		1	Cat. No. 10290-009	Air Sampler	VWR Scientific
	X		1	Cat. No. 18343-007	Tool Sterilizer	VWR Scientific
	X		1	Model RHA-100A	Microscope Cmpd	Olympus Corporation
	X		1	Model SZ3-TR	Microscope, Disc	Olympus Corporation
	X		24		Drawer Slides	Manufacture
	X		12		Drawers	Manufacture
	X		1		Air Flow Wrk Srfce	Manufacture

Table 4-12. Breadboard Parts List, Contd

USED IN MODULES 1	2	3	NO. REQ.	PART NUMBER	DESCRIPTION	NOTES - SOURCE - SIZE - MATERIAL
	X		3		Equip Restraints	Manufacture
	X		1		Kit & Strg Hsg	Manufacture
X			1		Filler Plate	Mfg. 18 x 30 x 3 6061 Al Sht Iridite
X			1		Liquid Tank	Purchase Commercial
X	X		1		Shroud Assy	Manufacture
X			8		Cage (Modified)	General Dynamics/Convair
X			1		Cage Module	General Dynamics/Convair
X			1		C.M. Front Mount	$\frac{1}{2}$ x 19 x 30 6061 Al Plt Iridite
	X		1		Piano Hinge	1 x 1 x 10 inches
	X		1		Cable Tray Door	.18 x 12 x 4 6061 Al Sht Iridite
	X		1		Cplr Cover Panel	.18 x 12 x 6 6061 Al Sht Iridite
	X		1		Cplr Cover Panel	.18 x 12 x 5 6061 Al Sht Iridite
	X		1		Wre & Cable Strg Try	.06 x 28 x 29 6061-T6 Al Sht Iridite
	X		1		Coupler Supprt Hsg	.06 Al Sht 6061-T6 31 x 15 Iridite
	X		1	VR 3/L Series-3	Card Frame Rack	Elco Mfg. Co.
	X		16	50-15A-20 (Series 250)	Connectors	Cinch Mfg. Co.
	X		1	Model 820	Numerical Display	Datascan Electronics
	X		1	Model 214	Oscilloscope	Tektronik
		X	1	Cat. No. 55699-150	Refrigerator	VWR Scientific
	*		1	Model IL 313	Blood Gas Analyzer	Instrumentation Lab Inc.
	X		1		Auto. Pot. Elect. Analyr	GFE - JSC Development Item
	*		1	Cat. No. 454	Blood Sample Proc.	International Equip. Co.
	X		1		Blood Sample Proc.	GFE - Skylab Unit

*Alternate Commercial Items

Table 4-12. Breadboard Parts List, Contd

USED IN MODULES 1	2	3	NO. REQ.	PART NUMBER	DESCRIPTION	NOTES - SOURCE - SIZE - MATERIAL
X			1	Model MRPU	Blower (Type 701)	Rotron Mfg. Co.
		X	1	Cat. No. 35785-001	Incubator	VWR Scientific
		X	1	Model 400	Mass Spectrometer	Granville Phillips Co.
			2	PM-78A	Angles	Emcor Div. of Borg Warner
X			1	SP-125A	Side Panel	Emcor Div. of Borg Warner
	X		1	SP-125A-FL	Side Panel	Emcor Div. of Borg Warner
X			1	DO-52C-LV-30-LH	Door	Emcor Div. of Borg Warner
	X		1	DO-52C-LV-30-RH	Door	Emcor Div. of Borg Warner
		X	2	ASPX-FIX-251900	Ins Frame Side Panel	Emcor Div. of Borg Warner
		X	1	APNS-XXX-002224	Ins Frame Btm Panel	Emcor Div. of Borg Warner
X	X		2	UM-506	Plug-In Strip	Emcor Div. of Borg Warner
	X		2	CR-25A-30	Cradle Slide	Emcor Div. of Borg Warner
	X		4	CS-25A	Case Slides	Emcor Div. of Borg Warner
	X		10	HW-309	Circular Drwr Pulls	Emcor Div. of Borg Warner
X	X		2	FR-525A	Vertical Frame	Emcor Div. of Borg Warner
X	X		2	RSA-1B-30-25	Retractable Shelf	Emcor Div. of Borg Warner
X			1	SH-25A-30	Equip Shelf	Emcor Div. of Borg Warner
		X	1	PNA-19-24	Closure Panel	Emcor Div. of Borg Warner
		X	1	PNA-22-24	Closure Panel	Emcor Div. of Borg Warner
		X	1	PNA-10-24	Closure Panel	Emcor Div. of Borg Warner
		X	1	PNA-8-24	Closure Panel	Emcor Div. of Borg Warner
		X	1	AFRT-XXX-250024	Instrument Frame	Emcor Div. of Borg Warner
		X	1	ACSX-XXX-250024	Cradle Slide	Emcor Div. of Borg Warner
		X	1	AESX-XXX-250024	Equip Shelf	Emcor Div. of Borg Warner

4.2.6 MEDICAL DIAGNOSTIC AND TREATMENT MODULE. In future post-Skylab manned space missions, a capability will probably be provided on all flights to perform limited medical examination and first aid and to obtain backup medical support through telemetry and voice communications from physicians located on the ground. If equipment for such medical procedures is provided as a spacecraft subsystem on all flights, then selected items could be used to support biomedical research. Since a medical diagnostic and treatment kit for future missions has not yet been defined, a study was performed during Task C to describe such a kit to determine how it might impact or complement biomedical research missions with COLs. The kit will be an easily transportable package of equipment required for inflight examination, diagnostic tests, first aid, and stabilization of ill crew members during transport to ground facilities.

The kit must be lightweight, make maximum use of existing equipment, and be packaged to conform with the 35.6 by 43.2 by 50.8 cm (14 by 17 by 20 inch) module size. It must have minimum power requirements and be designed for operation with minimum interface with vehicle facilities. The kit must be capable of being transported to and used in any occupied compartment of the space vehicle.

The proposed concept will provide the diagnostic, microscope, and medical accessory kits used in Skylab missions discussed on pages 34 through 39 of "Skylab and the Life Sciences," NASA Manned Spacecraft Center, February 1973. A suture kit, waste storage kit, work bench, equipment restraint device, and emergency light will be provided in a single carrying case.

In a zero-g environment, the carrying case would be secured to any convenient vehicle structure and opened to enable access to all kits and contained equipment. This concept avoids requirements for power sources or refrigeration by using a waste storage container that chemically treats solid and fluid wastes to prevent growth or gas evolution. The waste storage device consists of two 1-liter plastic containers. Each container has a hinged lid that can be securely clamped in the closed position, with a rubber diaphragm stretched across the opening beneath the lid. The diaphragm is slit to enable waste objects such as pipettes, slides, cotton swabs and fluids to be pushed through the slit without loss of contained waste materials from the container in the zero-g environment.

The capability provided by this medical, diagnostic, and treatment unit is shown on Table 4-13. A review of the equipment used in this preliminary working model indicates that only those items listed under "Diagnostic" procedures could have potential for any practical dual-purpose usage. Weight and volume of these items, with the possible exception of the high-power microscope, are not significant. Accordingly, the possibility of degrading the effectivity of the medical diagnostic and treatment kit by having some of the equipment items tied up at some remote position in the spacecraft argues against the dual usage. The conclusion drawn from this quick look at this topic was that the COL concept should be self-sufficient and not based on use of any equipment items provided for emergency medical diagnostic and treatment procedures.

Table 4-13. Medical Diagnostic and Treatment Kit

EQUIPMENT FOR INFLIGHT EXAMINATION, DIAGNOSTIC TESTS, FIRST AID, AND STABILIZATION OF ILL CREW MEMBERS DURING TRANSPORT TO GROUND FACILITIES.

(PACKAGED IN ONE 35.6×43.2×50.8 CM (14×17×20 INCH) CARRYING CASE)

DIAGNOSTIC	MEDICAL ACCESSORY	SURGICAL
STETHOSCOPE	ANTIBIOTICS	LOCAL ANESTHETIC
SPHYGMOMANOMETER	ANTIMOTION DRUGS	SYRINGES
THERMOMETER	ANALGESICS	NEEDLES
BLOOD ANALYSIS EQUIPMENT	ANTIHISTIMINICS	HEMOSTATS
URINALYSIS EQUIPMENT	BANDAGES	NEEDLE HOLDER
MICROSCOPE *	OINTMENTS	SCALPEL
BIOELECTRODES **	MISC. DRUGS	STERILE GAUZE
ELECTROLYTE SPONGES **		SUTURES
		SCISSORS
		STERILE GLOVES
		70% ALCOHOL

*HIGH POWER MICROSCOPE FOR TOTAL & DIFFERENTIAL BLOOD COUNTS.

**PROVIDES DOWNLINK CAPABILITY FOR PHYSICIAN BACKUP FROM NASA MISSION CONTROL.

4.3 MAN/SYSTEMS INTEGRATION (MSI) COL CONCEPTUAL DESIGN

For MSI research, only a Category A (227 to 318 kg) COL was defined. The layout concept selected by NASA for final evaluation was Concept H_2, described in Section 3.3. However, the human sensory and physiological equipment was omitted and photography and audio taping facilities were added. The resulting design concept drawing is shown in Figure 4-12 and the equipment list and properties in Table 4-14. More detail on each equipment item may be found in Volume III.

The basic capability of this COL is audio-visual measurements. It would be used during cargo-handling studies; assembly, deployment maintenance, and repair studies; group dynamic studies; and locomotion and restraint studies. Storage volume is provided for experiment-specific equipment. Typical examples of this equipment are special tools, equipment restraint devices, various fasteners, mass transfer mechanisms, and task simulator kits.

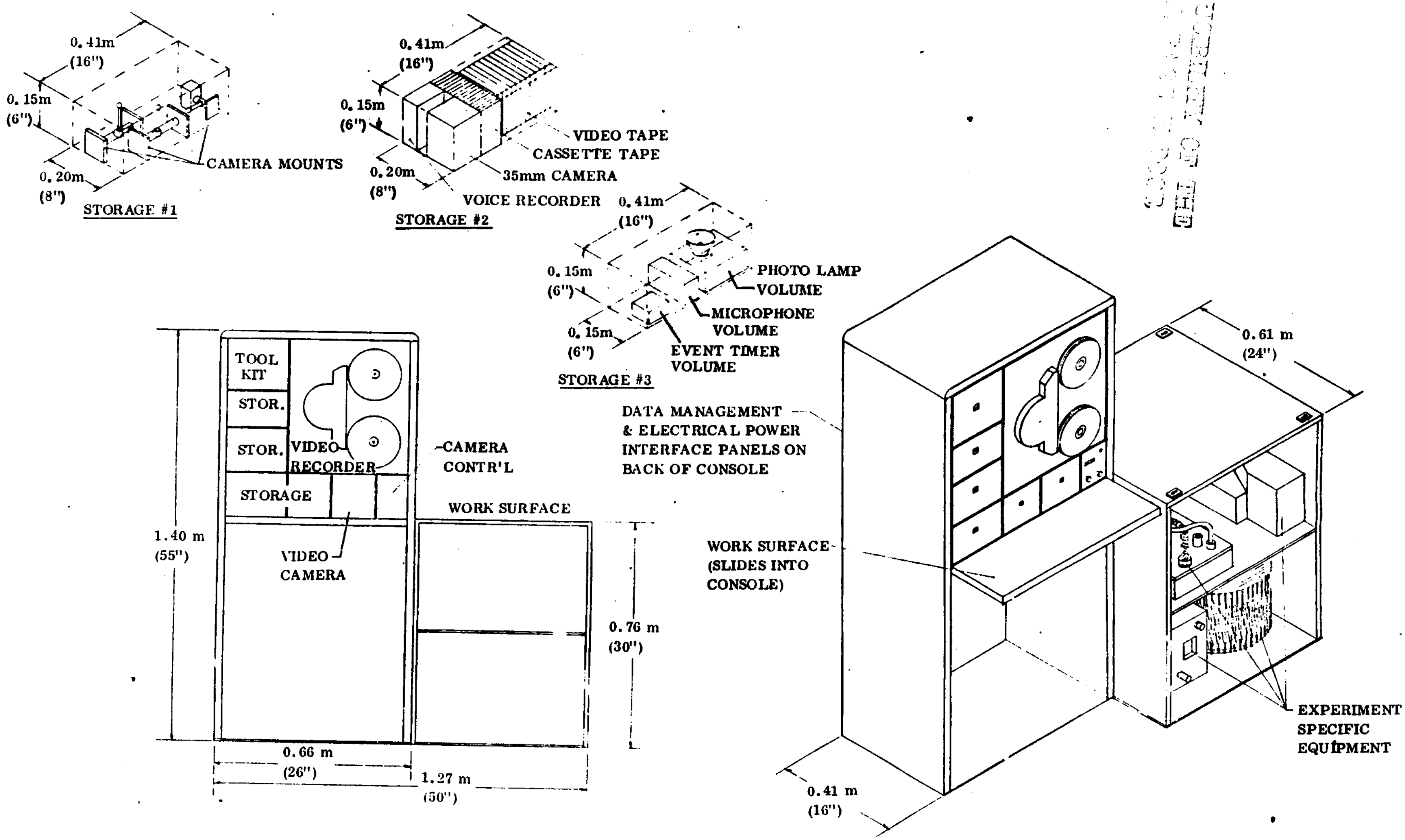


Figure 4-12. MSI COL Conceptual Design

Table 4-14. MSI COL Equipment Item Weight, Volume, and Power

E.I. NO.	EQUIPMENT ITEMS (E.I.'S)	WEIGHT FOR 7-DAY MISSION, KG	VOLUME, DM^3	POWER, WATTS
C38	CAMERA, VIDEO, COLOR	7.7	6.2	69
C34	CAMERA, 35 MM	2	2	0
C190	CAMERA MOUNTS	3	3	0
C191	CAMERA TIMER, VIDEO	4	3	10
C55A	CREW MOBILITY AIDS	2.3	2.8	0
C55B	CREW RESTRAINTS	4	10	0
C196	EQUIPMENT RESTRAINTS	0.5	1	0
C113	KIT, GENERAL TOOL	4.5	14.2	50
C202	LAMP, PORTABLE PHOTO	6.3	6	150
C116	LOG BOOK	0.5	0.4	0
C126	MICROPHONE	0.5	0.5	0
C180	TIMER, EVENT	0.2	0.2	0
C176	VIDEO TAPE	5	11	0
C207	VIDEO TAPE RECORDER	22.3	50	80
	RESEARCH E.I. TOTALS	62.8 (138 LB)	110.3 ($3.89 FT^3$)	359
	PLUS THE WEIGHT OF:			
	RESEARCH EQUIPMENT MODULE	16.3		
	EXPERIMENT SPECIFIC EQUIPMENT MODULE	8.6		
	TOTAL	87.7 (193 LB)		

4.4 LSPS COL CONCEPTUAL DESIGN

The final LSPS design concept is shown in Figures 4-13 and 4-14. This concept will support all major research areas within the LSPS FPE, including liquid- and gas-handling equipment experiments and crew-interfacing equipment as described in Section 2.3. The COL concept consists of two modules: upper and lower. Each has been sized to fit through a 102-cm (40-inch)-diameter hatch. The upper module contains the gas analyzers and instrumentation that the crew will probably be monitoring during experiment procedures. This includes an infrared gas analyzer, gas chromatograph, strip chart recorder, mass spectrometer, and numeric display. Interconnecting lines running to the upper module from the lower module and the test article should be limited to small gas sample lines to the gas analyzers and electrical lines to all equipment.

The lower module contains less frequently used equipment, storage areas, and fluid storage vessels. It also contains the major lines for interconnection with the various test articles. These lines terminate in sealing-type connectors to which the test article lines can be attached. They provide low-temperature coolant, high-temperature coolant, vacuum, liquids, gases, and electrical power and instrumentation interconnections.

The test device is accommodated between the upper and lower modules in a space approximately 1 m wide by 0.5 m high by 0.5 m deep. This was judged sufficient to

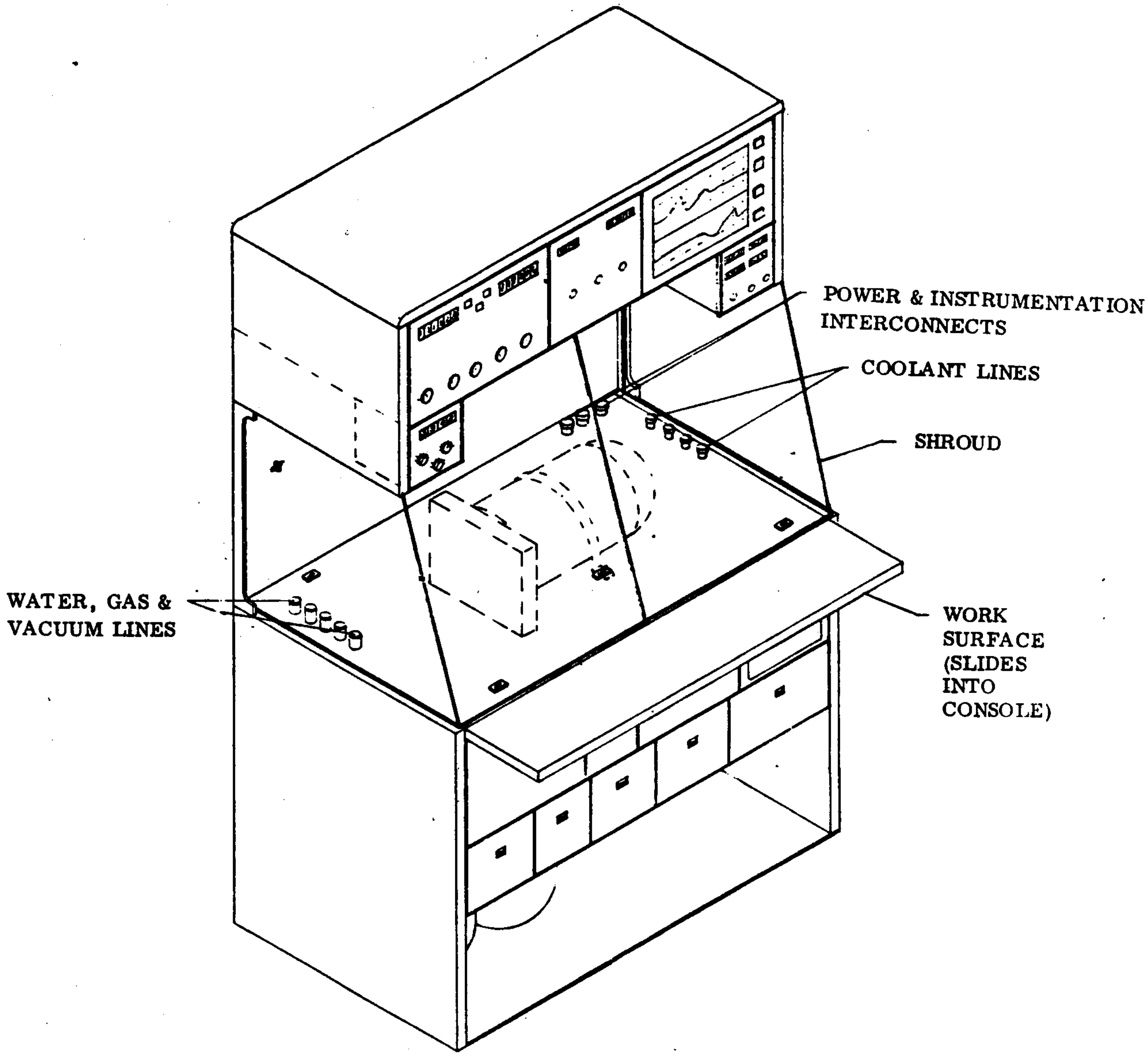


Figure 4-13. LSPS COL

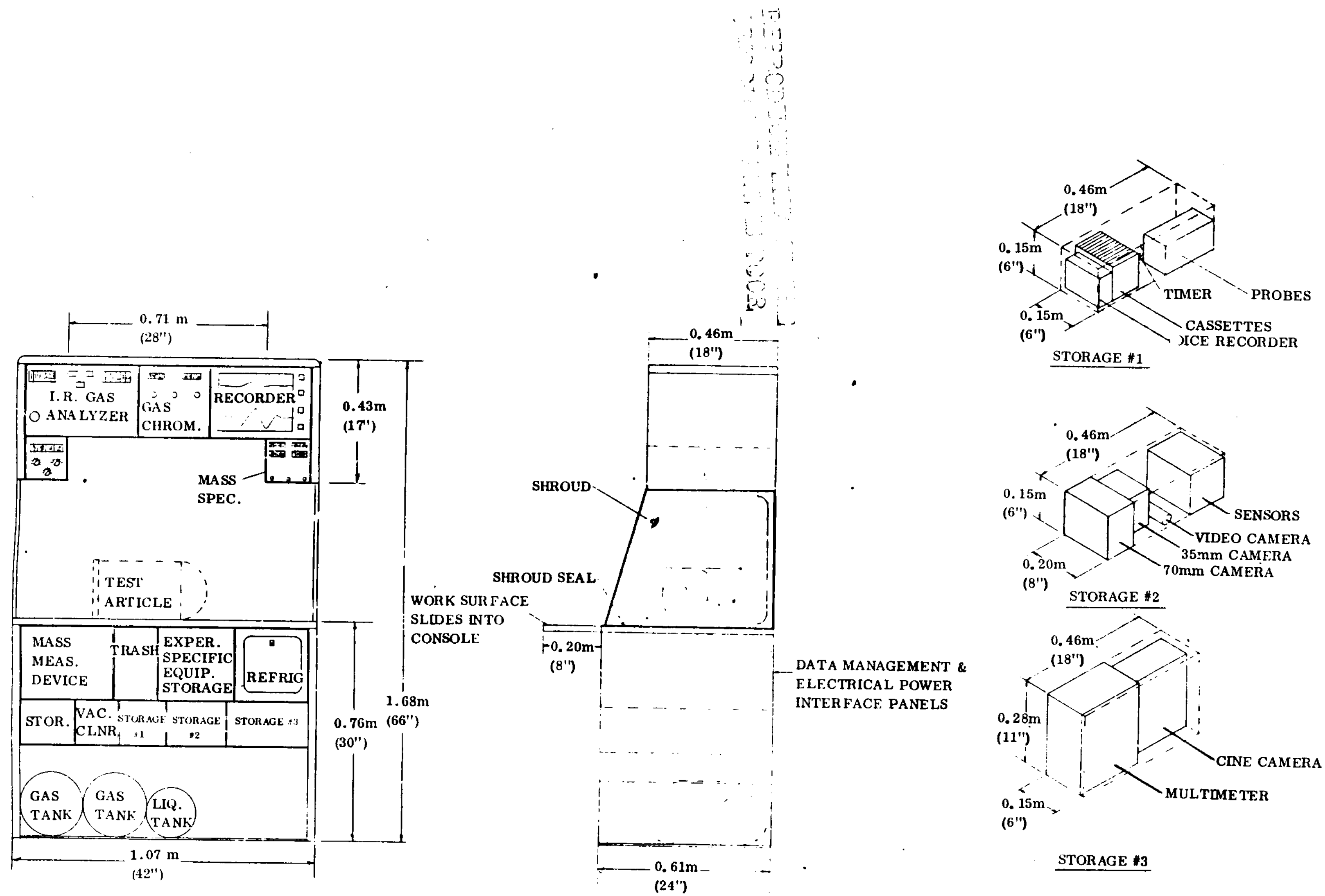


Figure 4-14. LSPS COL Conceptual Design

accommodate most test articles, which will generally be of a non-operational reduced size for spaceflight testing. Also, the height of the test enclosure on the COL can be increased by spacing the upper and lower modules further apart. The test enclosure can also be sealed in an environmental shroud, as shown in Figures 4-13 and 4-14. This shroud is intended as a safety device for use during testing of devices that contain toxic or flammable liquids. Thus, if a leak develops, the fluids will be contained within the shrouded volume. This volume will be continuously monitored so that potential contaminants can be detected immediately and corrective steps taken before they lead to a hazardous condition for the crew or the mission.

Equipment items contained in the LSPS COL are listed in Table 4-15 and described in more detail in Volume III. Equipment items not needed for any individual experiment could be offloaded for that flight. Other items of an experiment-specific nature will be required for the experiments and will add to the weight, power, and possibly volume of the LSPS COL. These items are of such a variable nature, depending upon the test, that no attempt has been made to account for them in the final equipment tabulation.

Table 4-15. LSPS COL Equipment Item Weight, Volume, and Power

E.I. NO.	EQUIPMENT ITEMS (E.I.'S)	WEIGHT FOR 7-DAY MISSION, KG	VOLUME, DM^3	POWER, WATTS
C32	CAMERA, CINE	5	5	13
C37	CAMERA, VIDEO, BLACK/WHITE	4.4	3	15
C34	CAMERA, 35MM	2	2	0
C55A	CREW MOBILITY AIDS	2.3	2.8	0
C55B	CREW RESTRAINTS	4	10	0
C192	DISPLAY, NUMERIC	2	4	2
C196	EQUIPMENT RESTRAINTS	0.5	1	0
C76C	FILM, CINE	2.2	2.2	0
C167C	FILM CABINET	9.1	9	0
C197	FLOWMETERS	2	2	4
C89	GAS CHROMATOGRAPH	10	20	50
C93A	GAS SUPPLY VESSELS	8.1	36	0
C199	INFRARED GAS ANALYZER	11.3	42.6	50
C201	KIT, CHEMICAL SAMPLING	1.5	5	0
C106A	KIT, CLEAN-UP	1.5	5	0
C113	KIT, GENERAL TOOL	4.5	14.2	50
C202	LAMP, PORTABLE, PHOTO	6.3	6	150
C203	LIQUID TANKS (WET WT.)	9	16.5	0
C116	LOG BOOKS	0.5	0.4	0
C122	MASS MEASUREMENT DEVICE	15.9	20	7
C91	MASS SPECTROMETER	11.3	16.4	30
C204	PLUMBING	10	6	0
C205	RECORDER, STRIP CHART (BATT. POW.)	12.5	16.9	0
C153	RECORDER, VOICE	1	0.4	0
C83	REFRIGERATOR	5	17	15
C153B	SENSORS, MISCELLANEOUS	2	2	4
C155B	SHROUD, ENVIRONMENTAL	4.5	5.7	0
C177	TEMPERATURE PROBES	0.3	0.4	0
C180	TIMER, EVENT	0.2	0.2	0
C48	VACUUM CLEANER	2.3	10	100
C118I	VACUUM MANIFOLD	9.1	28.3	0
C185	VOLT-OHMMETER (VOM), (BATT. POW.)	2	2.4	0
C181G	WASTE STORAGE CONTAINER	1	28.3	0
	RESEARCH EQUIPMENT TOTALS	163.3 (360 LB)	340.7 ($12.03 FT^3$)	490
	PLUS THE WEIGHT OF: RESEARCH EQUIPMENT MODULE	30		
	TOTAL	198.0 (437 LB)		

SECTION 5

COL INTEGRATION STUDIES (TASK C)

Several integration areas pertaining to the final COL concepts were studied. These included COL requirements for electrical power, data management, Spacelab installation, and special operational considerations and are discussed in the following sections. Overall interface summaries are presented in Section 5.5.

5.1 ELECTRICAL POWER REQUIREMENTS

Electrical power requirements were estimated for each of the final COLs. These included: 1) Category A COLs (227 to 318 kg) for research in biomedicine/biology, life support and protective systems (LSPS), and man/systems integration (MSI); 2) a Category B COL (91 kg) for biomedical research; and 3) three Category C COLs (23 kg) for biomedical research. Electrical power requirements for each of these COLs are detailed in Table 5-1 through 5-4. For each COL, the power-consuming equipment items (EIs) are listed along with:

a. EI operating power (steady state power while operating).

b. EI "on-time" (the period of time during the two-hour COL use-time during which the EI would be on).

c. EI average power consumption, as obtained by averaging over the two-hour per day COL use-time.

d. The contribution of each EI to an estimated peak power requirement (obtained by estimating which EIs might be operating simultaneously to give maximum power and including the operating power of these EIs in the column marked peak power contribution).

e. Total "on-time" per day for each EI.

f. Energy consumption for each EI in Watt-hr/day (obtained by multiplying the total on-time by the operating power).

g. Standby power, if existent (obtained as shown in the tables).

Table 5-1 shows the electrical power requirements of the EIs in the combined biomedical/biology COL, Category A (500 to 700 lb). For example, the automated potentiometric electrolyte analyzer (EI C188) requires 100 Watts when operating, and was assumed to be in use 0.5 hour during the two-hour use period of this COL. During this two hours, the average power contribution of the electrolyte analyzer is 25 Watts and the peak power contribution is 100 Watts. Total on-time is 0.5 hr and the daily energy requirement is 50 Watt-hours. A second example is the eight cages for small vertebrates.

Table 5-1. Estimated Electrical Power Requirements for the Combined Biomedicine/Biology COL, Category A (500 to 700 lb)

EQUIPMENT ITEM	OPERATING POWER, WATTS	POWER DURING 2-HR COL USE TIME			ENERGY CONSUMPTION	
		ON-TIME, HRS	AVERAGE POWER, WATTS	PEAK POW., CONTRIBUTION, WATTS	TOTAL ON-TIME HRS/DAY	ENERGY, WATT-HRS/DAY
AIR PARTICLE SAMPLER	50	0.2	5	0	0.2	10
AUTO. POTENTIOMETRIC ELECTROLYTE ANALYZER	100	0.5	25	100	0.5	50
BLOOD SAMPLE PROCESSOR CENTRIFUGE	100	0.2	10	0	0.2	20
CAGE, SMALL VERTEBRATES	72	2.0	72	72	12.0	864
CAMERA, VIDEO COLOR	69	0.25	9	69	0.25	17
COUPLERS	24	2.0	24	24	4.0	96
DISPLAY, NUMERIC	2	2.0	2	0	2.0	4
VENTILATION UNIT, SMALL VERTEBRATES	40	2.0	40	40	24.0	960
FREEZER, GENERAL	50	2.0	50	50	8.0	400
FREEZER, LOW TEMP.	400	2.0	400	400	8.0	3200
INCUBATOR	5	2.0	5	5	24.0	120
KIT, GENERAL TOOL	50	negl.	0	0	0	0
LAMP, PORTABLE PHOTO	150	0.25	19	150	0.25	38
MASS SPECTROMETER	30	2.0	30	30	24.0	720
MICROSCOPE, COMPOUND	50	0.2	5	0	0.2	10
MICROSCOPE, DISSECTING	63	0.2	6	63	0.2	13
OSCILLOSCOPE	Battery	-	-	-	-	-
REFRIGERATOR	15	2.0	15	15	8.0	120
SENSORS	4	2.0	4	4	24.0	96
STERILIZER, TOOL	110	0.1	6	0	0.1	11
VACUUM CLEANER	100	0.2	10	0	0.2	20
WORK SURFACE, AIRFLOW	75	0.5	19	75	0.5	38
TOTALS	1559		756	1099		6807

AVERAGE 22 HOUR STANDBY POWER IS $\frac{6807-(2)(756)}{22} = 241$ WATTS.

Table 5-2. Estimated Electrical Power Requirements of the Biomedical COL, Category B (200 lb)

EQUIPMENT ITEMS	OPERATING POWER	POWER DURING 2-HR COL USE-TIME			ENERGY CONSUMPTION	
		ON-TIME, HRS	AVERAGE POWER, WATTS	PEAK POWER CONTRIBUTION, WATTS	TOTAL ON-TIME HRS/DAY	ENERGY, WATT-HRS DAY
BLOOD GAS ANALYZER	55	0.6	17	55	0.6	33
BLOOD SAMPLE PROCESSOR CENTRIFUGE	100	0.3	15	100	0.3	30
COUPLERS (6 REQD.)	12	2.0	12	12	4.0	48
DISPLAY, NUMERIC	2	2.0	2	2	2.0	4
FREEZER, GENERAL	50	2.0	50	50	8.0	400
FREEZER, LOW TEMP.	400	2.0	400	400	8.0	3200
REFRIGERATOR	15	2.0	15	15	8.0	120
WORK SURFACE, AIRFLOW	75	0.4	15	0	0.4	30
TOTALS	709		526	634		3865

AVERAGE STANDBY POWER FOR 22 HOURS PER DAY IS $\frac{3865 - 2(526)}{22}$ = 127 WATTS.

Table 5-3. **Estimated Electrical Power Requirements of the Biomedical COLs, Category C (50 lb)**

EQUIPMENT ITEMS	OPERATING POWER	POWER DURING 2-HR COL USE-TIME: ON-TIME HRS	POWER DURING 2-HR COL USE-TIME: AVERAGE POWER, WATTS	POWER DURING 2-HR COL USE-TIME: PEAK POWER CONTRIBUTION, WATTS	ENERGY CONSUMPTION: TOTAL ON-TIME HRS/DAY	ENERGY CONSUMPTION: ENERGY, WATT-HRS DAY
COL C1						
AUTO. POTENTIOMETRIC ELECTROLYTE ANALYZER	100	0.5	25	100	0.5	50
AVERAGE STANDBY POWER FOR COL C2 IS 0.						
COL C2						
BLOOD SAMPLE PROCESSOR CENTRIFUGE	100	0.5	25	100	0.5	50
FREEZER, LOW TEMPERATURE	400	2.0	400	400	12.0*	4800
TOTALS	500		425	500		4850
AVERAGE STANDBY POWER FOR COL C2 FOR 22 HOURS PER DAY IS [4850-2(425)] /22 = 181 WATTS.						
COL C3						
COUPLERS (8 REQD.)	16	2.0	16	16	2.0	32
FREEZER, GENERAL	50	2.0	50	50	8.0	400
TOTALS	66		66	66		432
AVERAGE STANDBY POWER FOR COL C3 FOR 22 HOURS PER DAY IS 432-2(66) /22 = 14 WATTS.						

*NOTE: THE ON-TIME FOR THE LOW TEMPERATURE FREEZER IS 12 HOURS/DAY FOR THIS COL COMPARED TO 8 HRS/DAY FOR THE FREEZER IN THE CATEGORY A&B COL'S. THE DIFFERENCE RESULTS FROM THE USE OF SPACECRAFT COOLANT FOR THE CATEGORY A&B COL FREEZERS AND THE USE OF A SELF-CONTAINED NON-LIQUID COOLED UNIT FOR THE SMALLER, MORE PORTABLE CATEGORY C COL. THE CATEGORY C COL WILL REJECT THE FREEZER HEAT LOAD TO THE CABIN AIR.

Table 5-4. Estimated Electrical Power Requirements of the MSI and LSPS COLs, Category A (500 to 700 lb)

EQUIPMENT ITEMS	OPERATING POWER	POWER DURING 2-HR COL USE-TIME			ENERGY CONSUMPTION	
		ON-TIME HRS	AVERAGE POWER, WATTS	PEAK POWER CONTRIBUTION, WATTS	TOTAL ON-TIME HRS/DAY	ENERGY WATT-HRS DAY
LSPS COL						
CAMERA, CINE	13	0.1	1	0	0.1	1
CAMERA, VIDEO, B/W	15	0.1	1	15	0.1	2
DISPLAY, NUMERIC	2	2.0	2	2	2.0	4
FLOWMETERS	4	2.0	4	4	24.0	96
GAS CHROMATOGRAPH	50	1.0	25	50	1.0	50
I.R. GAS ANALYZER	50	2.0	50	50	24.0	1200
KIT, GENERAL TOOL	50	NEGL.	0	0	NEGL.	0
LAMP, PORTABLE PHOTO	150	0.2	15	150	0.2	30
MASS MEASUREMENT DEVICE	7	0.1	NEGL.	0	0.1	1
MASS SPECTROMETER	30	2.0	30	30	24.0	720
REFRIGERATOR	15	2.0	15	15	8.0	120
SENSORS	4	2.0	4	4	24.0	96
VACUUM CLEANER	100	0.1	5	0	0.1	10
TOTALS	490		152	320		2330
AVERAGE STANDBY POWER FOR 22 HOURS PER DAY IS [2330-(2)(152)] /22 = 92 WATTS.						
MSI COL						
CAMERA, VIDEO COLOR	69	0.5	17	69	0.5	35
CAMERA TIMER, VIDEO	10	0.5	3	10	0.5	5
LAMP, PORTABLE PHOTO	150	0.5	38	150	0.5	75
VIDEO TAPE RECORDER	80	0.5	20	80	0.5	40
TOTALS	309		78	309		155
AVERAGE STANDBY POWER IS 0.						

Table 5-5. Electrical Power Summary for Carry-On Laboratories (Preliminary)

LABORATORY	TOTAL POWER OF ALL E.I.'S, WATTS	POWER DURING 2-HR COL USE PERIOD		TOTAL ENERGY CONSUMPTION, W-HR/DAY	AVERAGE STANDBY POWER FOR 22 HRS/DAY, WATTS
		AVERAGE WATTS	PEAK WATTS		
COMBINED BIOMEDICAL/BIOLOGY, CATEGORY A (500-700 LB)	1559	756	1099	6807	241
BIOMEDICAL, CATEGORY B (200 LB)	709	526	634	3865	127
BIOMEDICAL, CATEGORY C_1 (50 LB)	100	25	100	50	0
BIOMEDICAL, CATEGORY C_2	500	425	500	4850	181
BIOMEDICAL, CATEGORY C_3	66	66	66	432	14
LS/PS*, CATEGORY A	490	152	320	2330	92
MSI*, CATEGORY A	309	78	309	155	0

*POWER VALUES DO NOT INCLUDE EXPERIMENT SPECIFIC EQUIPMENT

These require 72 Watts for lights, which were assumed to be on for a total of 12 hours/ day, giving a daily energy consumption of 864 Watt-hours. On-time during COL use is expected to be two hours, which results in both an average and peak power consumption of 72 Watts during the two hours of COL use.

The pertinent totals for the biomedical/biology COL are shown at the bottom of Table 5-1. The first total is shown merely for comparison with the second and third. That is, the total operating power for all EIs, if on simultaneously, would be 1559 Watts. Average power is about one-half of this amount or 756 Watts, and peak power is about two-thirds or 1099 Watts. The 756 Watts is the average power consumption of the biomedicine/biology COL during the assumed use period of two hours. The 1099 Watts would be the maximum peak power expected during the same period. Thus, the supporting spacecraft electrical power subsystem must provide these power levels. It would also have to supply a total electrical energy of 6807 Watt-hours per day to this COL, and an average standby power level of 241 Watts.

Tables 5-2 through 5-4 show EI power analyses for the other COLs, all of which are similar to that discussed above. Table 5-5 summarizes total power requirements of each of the COLs. The Category A biomedicine/biology COL has the greatest requirements, and the Category B and C_2 COLs have the next largest. The largest power-consuming EI is the thermoelectric low temperature freezer. It represents most of the load in the biomedical Category B and C_2 COLs.

5.2 COL DATA MANAGEMENT

5.2.1 <u>COL DATA REQUIREMENTS.</u> In determining the data management requirements of the COLs, the philosophy used was consistent with minimum integration and maximum use of manual data-handling techniques. For example, many EIs such as the mass measurement device were assumed to contain localized signal-conditioning electronics and instrumentation that could be read and recorded manually by the operator. This philosophy was used to minimize the number of interfaces with the centralized command and data management subsystem (CDMS) and the number of software programs to be stored within the CDMS. The resulting independence of the COLs from the supporting spacecraft will add to its flexibility in use. Very few of the EIs in the various COLs require data handling by the central CDMS, and most of those that do require only a low rate of signal monitoring.

A list of the EIs requiring some form of data handling is presented in Table 5-6. The table contains the name and number of the EIs, indicates which of the three major COLs (Category A laboratories) uses them, and describes the measurement to be made. Continuous (24-hour) sampling of data is required for some EIs, and this is listed in the table in terms of the bits per second sampling rate to be handled by the data bus of the centralized CDMS. Also listed is the total daily estimated number of bits to be handled by the CDMS from each EI. These total daily values may be made up of intermittent bursts of high-rate data or continuous low-rate data. The sum of these total daily values indicates the total long-term data preservation requirement for the COLs, since 100 percent preservation was assumed in case later data analysis on the ground was desirable. Downlink requirements are also indicated in terms of the percentage of the total daily rate to be transmitted to the principal investigator on the ground for his review. This transmission need not be in real time. The displays required for each EI are also indicated in Table 5-6 and generally include a numeric readout device, as well as a warning device such as a light. A statement describing the type of data processing to be performed is also indicated. This is generally quite simple.

A few of the EIs listed in Table 5-6 are discussed below to exemplify the philosophy used in establishing the data management requirements. The first EI in the table is the blood electrolyte analyzer, which generates data at a low rate (although it does require computer processing). The analyzer accepts a blood sample (or urine sample) and measures, pH, CO_2, O_2, K^+, Na^+, Cl^-, Ca^{++}, and glucose. To measure these properties, known calibration samples are introduced into the detector cells before and after the unknown sample. The detector output corresponding to the known calibration samples is plotted and used to determine parameters of the unknown sample. A digital computer is currently being used to perform this processing, but specific information on the software program was unavailable. However, it should be quite simple and thus should not require much computer capacity. It was assumed that data from the electrolyte analyzer cells would be registered internally in the analyzer during each analysis and subsequently transmitted to the CDMS computer on command of the operator. Based on 30 minutes of operating the blood electrolyte analyzer per day, the amount of data to be handled by the CDMS would be about 5000 bits. This would all be stored for later analysis, and an estimated 20 percent would be downlinked.

The holding unit for small vertebrates (EI C103 in Table 5-6) requires intermittent monitoring of temperature. Temperature data was assumed to be monitored once per minute, requiring 7 bits of information for each sample. This results in a daily total of approximately 10 kbits. One-hundred percent of this data would be preserved, but none would be downlinked. If the temperature of the vertebrate cage module were to rise above a specified tolerable range, the vertebrates and/or the research results could be jeopardized. Thus, an alarm function is recommended. This would be activated as a result of a simple comparison to check to see if the temperature is out of the recommended range. The comparison could be performed by a local processor located at the COL or by the centralized DMS computer.

Couplers shown in Table 5-6 are the only EIs that result in a significant data rate to be handled by the CDMS. The 12 couplers are primarily used for monitoring electrophysiological data, and it was assumed that 2 of them would be required to monitor ECG or EEG data continuously. .At 500 samples per second and 7 bits per sample, this results in a continuous sampling rate of 7000 bps. The total daily rate from these two couplers is 605,000 kbits per day. In addition to these two couplers, other couplers were assumed to monitor lower rate data or to operate intermittently. Their contribution

Table 5-6. Estimated Data Management Properties of COL Equipment (Category A COLs)

Equipment Items (E.I. No.)	COL Using E.I. Biomed. Biol.	MSI	LS PS	Measurement Description	Continuous Data, bps	Daily Data Generated kbits/day	Daily Data Preserved %	Downlink Requirements %	Downlink Requirements kbits/day	Display Reqd	Processing Required by Computer or Other Means
Automated Potentiometric Electrolyte Analyzer (C188)	X			Measure pH, CO_2, O_2, K, Ca, Na, Cl, glucose. (Modified version of NASA's Automated Potentiometric Electrolyte Analysis System.)	0	5	100	20	2	Numeric	Linear interpolation program required
Couplers (C156)	X			Primarily to measure electrophysiological outputs such as ECG, EEG, etc.	7042	617000	100	1	6170	CRT & Numeric	Simple wave form analysis
Flowmeters (C197)			X	Monitor flow rates of fluids to & from test devices.	56	5040	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
Freezers, General (C80) & Lo Temp (C81)	X			Monitor temperature.	negl.	2	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
Gas Chromatograph (C32)			X	Measure detector output signal during analysis.	0	134	100	1	1	Numeric	Simple wave form analysis
Gas Supply Vessels (C93A)			X	Monitor pressure	negl.	20	100	0	0	Numeric & Warning	Trend Analysis
Holding Unit, Small Vertebrates (C103)	X			Monitor temperature in cage module.	negl.	10	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
Incubator (C198)	X			Monitor temperature.	negl.	1	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
Infrared Gas Analyzer (C199)			X	Measure detector output & sample select valve position continuously.	10	864	100	1	9	Numeric & Warning	Out-of-Tolerance Comparison
Mass Spectrometer (C41)	X		X	Record gas constituents for 96 scans/day.	negl.	50	100	10	5	Numeric	Type of processing to be determined.
Refrigerator (C83)	X		X	Monitor temperature.	negl.	1	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
Sensors (C153B)	X	X	X	Monitor various COL parameters (4 signals reqd).	negl.	40	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
Vacuum Manifold (C118I)			X	Monitor pressure.	negl.	10	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
Ventilation Unit, Small Vertebrates (C193)	X			Monitor ventilation blower current.	negl.	1	100	0	0	Numeric & Warning	Out-of-Tolerance Comparison
TOTALS FOR THE COL'S INDICATED	X				7042	617117	100		6177		
		X			0	40	100		0		
			X		66	6126	100		15		

was estimated at 42 bps to the continuous data rate and 12,000 kbits/day to the daily rate. This brings the data requirements for all couplers to 7042 bps continuous and 617,000 kbits/day, as shown in Table 5-6.

Total sampled data requirements of the COLs is indicated at the bottom of Table 5-6. The largest requirements are for the biomedical and small vertebrate COLs, which have a continuous data rate of about 7 kbps. The daily storage requirement is also primarily due to the 7 kbps continuous data rate from the couplers.

In addition to the data requirements outlined in Table 5-6, experiment-specific equipment will require data handling. Although this data requirement cannot be determined yet, it will probably not be substantially greater than that shown in the table for the common use equipment.

The biomedical Category B and C laboratories were also reviewed to determine their data-handling requirements. COLs C_1 and C_2 have negligible data-handling requirements and could perform their own data handling. COLs B and C_3 both require electrophysiological measurements on man, such as those associated with VCG measurements. These measurements were estimated to require a maximum of 21 kbps for up to 1 hour per day, resulting in 75.6 Mbits/day of total data to be handled. It was assumed that 100 percent of this data would be preserved for subsequent ground evaluation. The downlink requirement of this data was estimated to be 5 percent, or 3.78 Mbits/day.

Video data from the COLs must also be considered. Each Category A COL contains a video camera that will require a monitor and a recorder. The exception to this is the MSI COL, which contains its own video recorder because of its importance during MSI experiments. The biomedicine/biology and LSPS COLs have assumed that the supporting spacecraft would provide the video recording capability. A TV monitor is also a desirable item for use by all Category A COLs. The times the video cameras would be used for data acquisition are estimated as:

Biomedicine/Biology COL	30 min/day
LSPS COL	6 min/day
MSI COL	30 min/day

During these times. the recorder and monitor would be needed.

5.2.2 COMPARISON OF COL REQUIREMENTS TO SPACELAB CAPABILITY FOR DATA MANAGEMENT. The Spacelab is intended to house the Category A and B COLs. Thus, data management capabilities of this vehicle were compared to the worst-case requirements of the COLs (Table 5-7). Spacelab design is in the preliminary stages, and its characteristics have not yet been set. Therefore, information onthe CDMS was taken from Messerschmitt, Bolkow-Blohm (MBB) proposal to ESRO.

Table 5-7. Comparison of COL Data Management Requirements and Spacelab CDMS Capability

	CARRY-ON LAB REQUIREMENTS	SPACELAB CDMS CAPABILITY*
ON-BOARD DATA HANDLING		
Data Bus Maximum Data Rate, Mbps	0.007	1
Video Monitoring by CCTV, Hrs/Day	< 0.5	Continuous
Displays	CRT, Numeric & Warning	2 CRTs (Alphanumeric Capability), Digital Readouts, Warning Lights & Audible Alarms
Computer: Cycles/sec.	tbd	10^6 (1 μs cycle time)
Main Memory Storage, words	tbd	48K
DOWN-LINKED DATA HANDLING		
Digital Transmission to Ground, bits/day	6×10^8 (all data down-linked for preservation)	1.84×10^{12} (assuming 85% availability of TDRS and 50% time-sharing with video data)
Video Transmission to Ground, Hrs/Day	< 0.5 (primarily for purposes of preservation)	10.2 (assuming 85% availability of TDRS and 50% time-sharing with digital downlinked data)

*Control & Data Management Subsystem, based on preliminary studies by Messerschmitt, Bolkow-Blohm (MBB) and General Dynamics/Convair.

The proposed Spacelab CDMS contains a data bus data acquisition and control system capable of handling payload data at a rate of 1 Mbps. Although this capability will be used by payload elements other than the life sciences COLs, the latter will require only about 0.007 Mbps, as previously presented in Table 5-6. For video data, the Spacelab will contain a closed-circuit TV monitor and two black and white TV cameras. Continuous monitoring capability will thus be available, and the 1/2 hour or less required by the COLs should readily be accommodated. In the area of displays, the Spacelab will have two cathode ray tubes with alphanumeric display capability, digital readouts, warning lights, and audible alarms. Two alphanumeric keyboards are planned for command and control inputs, and a two-axis joystick controller will be provided for TV camera positioning control. These displays and controls will satisfy the COL requirements. Computer requirements of the COLs will depend on the specific experiments being conducted, but will probably not exceed the capability of the Spacelab computer, which has a 48k random access memory and a 1 μsec cycle time.

Spacelab is currently expected to downlink data via the Tracking and Data Relay Satellite (TDRS). This link will have a large capacity and most data to be preserved subsequent to flight will be downlinked and stored on the ground rather than onboard the Spacelab. Thus, the data to be preserved from Table 5-6 is compared with the TDRS downlink capability as shown in Table 5-7. It will be noted that the downlink requirement indication in Table 5-7 represents all of the daily data monitored as listed in Table 5-6, rather than that specified as the data required to be downlinked. This results from the fact that all life sciences COL data being monitored was assumed to require preservation for analysis subsequent to the flight. Since the Spacelab CDMS downlinks data to be preserved rather than storing it on board, the total daily data figure was used in Table 5-7 and is over 3 orders of magnitude less than the Spacelab capability. If the Spacelab CDMS were operating in a mode of onboard storage, the downlink requirement of the COL would be 6×10^6 bit/day as previously noted in Table 5-6. This would be over 5 orders of magnitude less than the Spacelab capability.

The COL TV data can also be downlinked by the Spacelab via TDRS. The TDRS downlink can be used to transmit digital or video data, but not both simultaneously. The TDRS should be available for Spacelab use about 85 percent of the time. The values in Table 5-7 were based on this factor and the assumption that the available downlink time would be equally shared between video and digital data downlinking. The latter 50 percent assumption is arbitrary, and will depend on the requirements of the total Spacelab payload complement.

In summary, the life sciences COLs will impose a very small load on the Spacelab CDMS compared to its overall capacity.

5.3 COL OPERATIONAL CONSIDERATIONS

Several operational aspects of the COLs were considered in this study and are presented in this section.

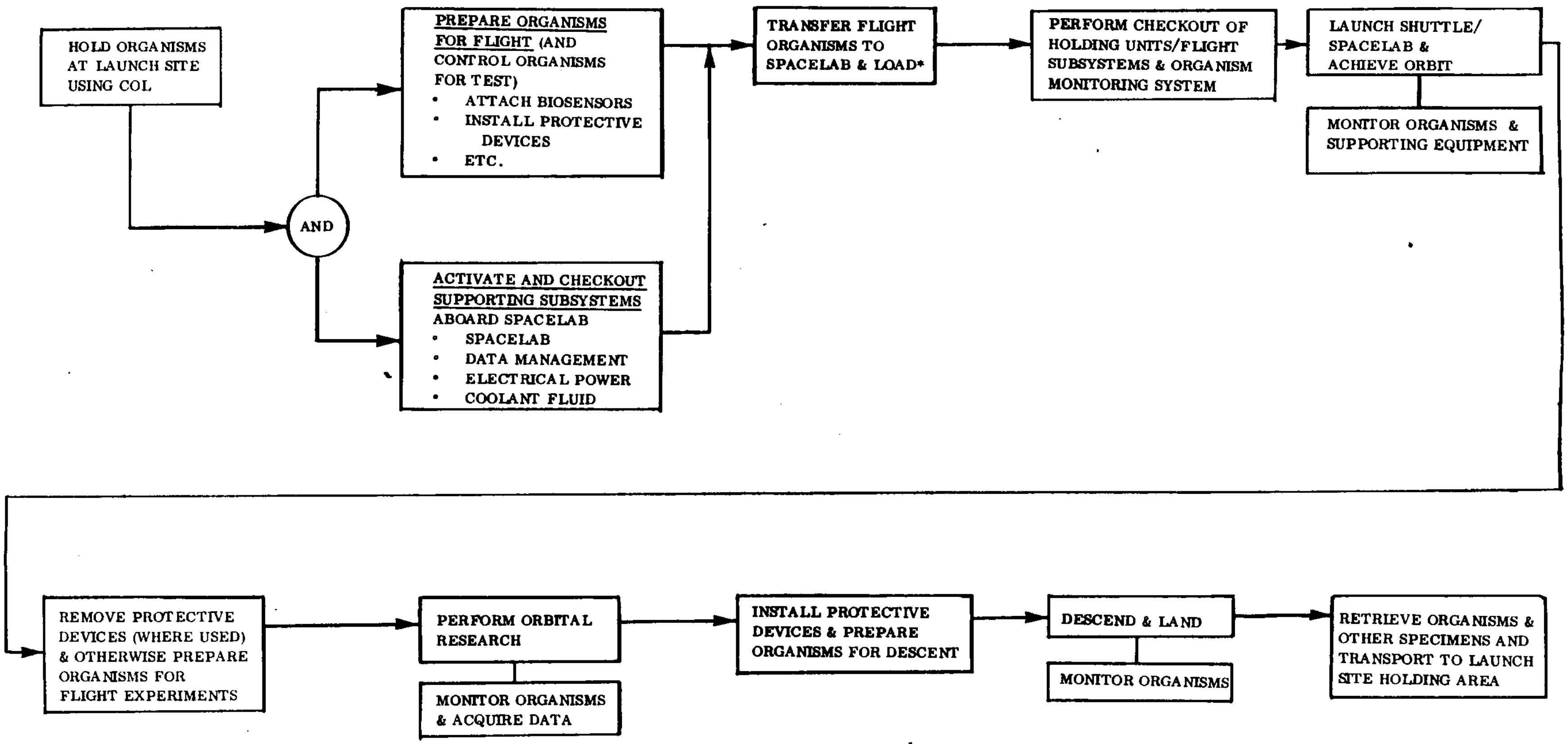
5.3.1 GROUND SUPPORT FACILITIES. The COLs, by their nature, are relatively independent and complete laboratory facilities. They require electrical power, liquid coolant, vacuum, and data acquisition and processing support equipment. Thus , the amount of support equipment is nominal, and the COLs could be used for ground support experiment procedures if they are designed for both ground and on-orbit operation. They could be used to support the research equipment, organisms and procedures 1) at the principal investigator's laboratory, 2) at the launch site, both before and after flight, and 3) in the flight vehicle. Making maximum use of the COLs in all three locations would tend to eliminate errors introduced by the use of different equipment.

5.3.2 BIOMEDICINE/BIOLOGY COL OPERATIONS. The biomedicine/biology COL presents more potential operational problems than the LSPS or MSI COLs because it contains living organisms and requires control experiments to be conducted on the ground for comparison of results. Ground support operations for biological research were considered in the previous Task C and D studies for the Dedicated 7- and 30-Day Life Sciences Laboratories, Reference 1. Some results of this study are applicable to the COLs and are included in the following discussion.

Ground support operations have been broken into phases of mission preparation, flight, and post-flight. Mission preparation activities for biological research may include determination of 1) experiment/flight compatibility using NASA flight simulators, 2) experiment protocols, and 3) baseline data on ground control organisms and the organisms intended for flight. These activities could take as long as 1 to 2 years, depending on the experiment being prepared. The COLs would be used to support the mission preparation activities as much as possible.

Following mission preparation, the organisms and applicable research equipment would be transported to the launch site and held until launch. This could also be done by using the COLs. During transportation of the organisms between facilities, however, the COL would require electrical power and data monitoring support. This could be provided by the bioexperiment support and transfer unit (BEST), which was described in the preceding Task C and D study on the dedicated and shared life sciences laboratories, Reference 1. The BEST is a self-contained unit for support of organisms in transit. For the COL, which contains an open-loop ventilation unit for the organisms rather than a closed-loop ECS, the BEST would be simpler than previously conceived. It would provide structural support, vibration isolation, data management, electrical power, and air purification provisions for the organism holding units in transit.

Following transfer of the COL and organisms to the launch site, various ground support and flight procedures will take place. An estimated sequence of major events is shown in Figure 5-1. Certain preparatory procedures will probably be performed on the organisms and/or the COL instrumentation and equipment. Examples include attachment of biosensors and checkout of electronic equipment, plus installation of protective devices if required. Biosensors, however, may also be implanted at the principal investigator's laboratory rather than at the launch site, depending on the specific experiment. Also,



*LOADING OF THE CAGE MODULES CONTAINING THE FLIGHT ORGANISMS WAS THE ASSUMED MODE OF LOADING.

Figure 5-1. Major Ground Support and Flight Operations for Biology Experiments supporting subsystems aboard the Spacelab will require checkout during countdown. It was assumed that the organisms would not be aboard the Spacelab during initial checkout. Rather, the COL equipment would be checked out and the organisms would be loaded on board later, during the last several hours of countdown.

Following launch and orbital insertion, the organisms may require preparation for the orbital research procedures, including removal of protective devices, if used. Ground support activities during the orbital phase will depend on the individual experiments being performed and may be performed on the ground in the principal investigator's laboratories or at a launch site biolaboratory using a COL. Following the orbital research period, organisms may be returned to earth, removed from the Spacelab, and transported to the launch site holding area or principal investigator biolaboratory. An overall concept of the mission scenario for bioexperiments is shown in Figure 5-2.

5.3.3 LSPS AND MSI COL OPERATIONS. Ground support and flight operations for LSPS and MSI research have been conducted in prior spaceflights. Thus, they were not considered as challenging as those required for biological organisms. Mission preparation activities for MSI experiments will involve crew training and experiments to establish baseline data, similar to those performed during past space flights. LSPS and MSI experiment-specific equipment must undergo flight compatibility checks and tests. Research protocols must be established and equipment transported to the launch site.

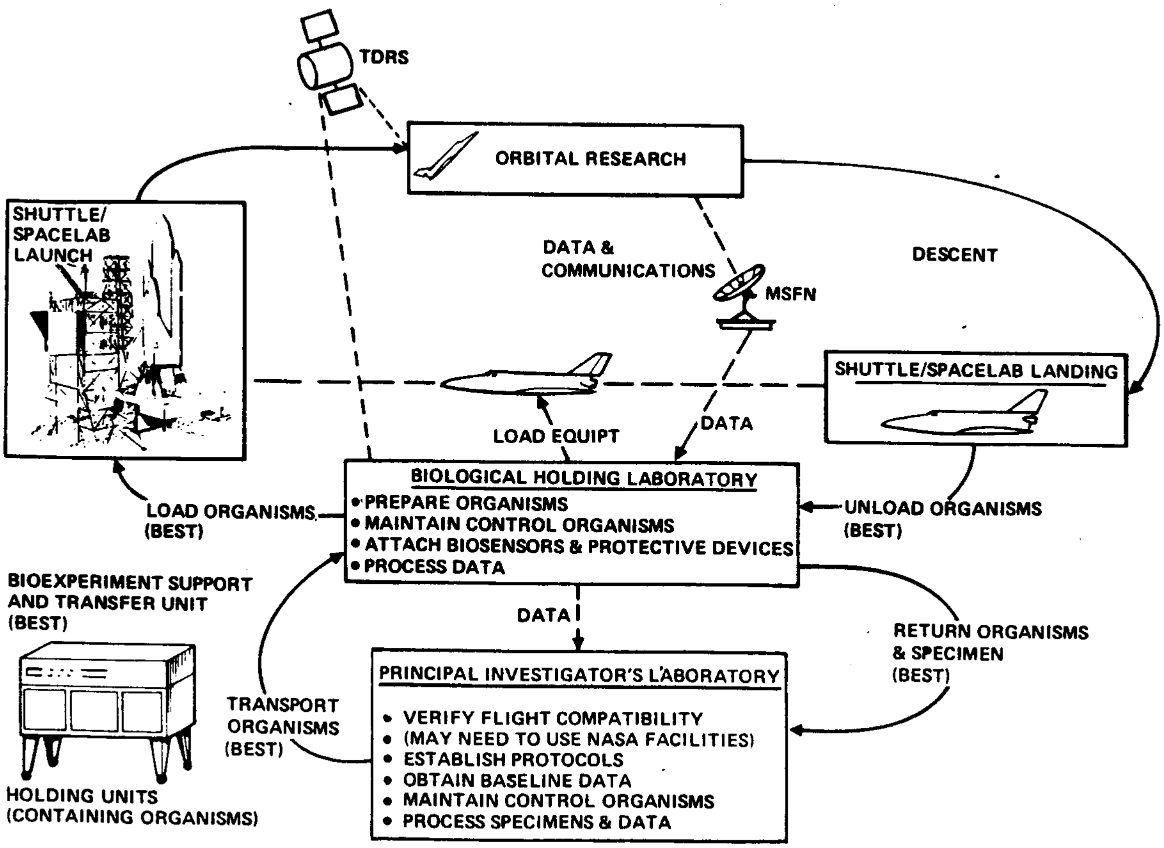


Figure 5-2. Bioexperiment Mission Scenario

During launch, orbital flight, and descent, the same general steps will be involved as were described above for bioexperiments. However, the absence of living organisms and perishable specimens will generally simplify the procedures. All equipment can be loaded early in the countdown period. No monitoring of equipment is foreseen during launch and descent, and early removal of specimens or equipment upon landing will not be required.

5.3.4 COL CONSUMABLES AND REFURBISHMENT. The consumables on all COLs affect both the weight as a function of mission duration and the refurbishment necessary on the ground between flights. To present data on these aspects, several tables were prepared showing weight differences between the 7- and 30-day COLs and noting the recommended refurbishment procedures. Table 5-8 lists all EIs in the combined biomedicine/biology COL and their weights for 7 and 30 days. Liquids contained in the automated potentiometric electrolyte analyzer, the organism water tank, and the consumables in the kits represent the major weight items. Total weight difference between the 30- and 7-day COLs is 25 kg (55 lb) for the biomedical/biology COL. Refurbishment procedures include replacing filters, batteries, lamps, absorbents, and kit items. Several EIs will require cleaning, repackaging, and refilling. Many items would undergo a general checkout prior to being committed to a subsequent flight; however, this was not noted in the table since it applies to virtually every item. EIs for the LSPS and MSI COLS are listed in Table 5-9. For the LSPS COL, the weight difference is 21.7 kg (48 lb) and for the MSI COL it is negligible.

5.4 INSTALLATION DRAWINGS OF THE COLS IN THE SHUTTLE/SPACELAB

Several drawings were made showing typical COL installations in the Spacelab. All Category A COLs are intended to be placed in the Spacelab. They are shown in Figure 5-3 in a possible arrangement that includes all three and yet occupies less than one-half the available Spacelab wall space intended for payload use. If all three were flown simultaneously, much of the equipment common to two or more of the COLs could be removed, leaving more space for experiment-specific equipment.

The Category B biomedical COL could be placed in the crew compartment of the Shuttle Orbiter or within the Spacelab. Figure 5-4 shows the COL in the Spacelab fitted within a rack structure. If this COL were placed in the Shuttle Orbiter crew compartment, it would take up slightly less volume than six of the standardized equipment containers (each 43 cm wide by 36 cm high by 51 cm deep). If the structure separating six of these containers (two wide and three high) were removed, it would provide a volume 86 cm wide by 108 cm high by 51 cm deep compared with dimensions of the Category B COL of 81 cm wide by 84 cm high by 56 cm deep. (See Section 4.2.3, Figure 4-6.) The COL would protrude from the front surface of the container rack structure by 5 cm (2 inches), exclusive of the deployable work surface of the COL.

Category C biomedical COLs were all configured to fit within one or more individual standardized container volumes in the Shuttle Orbiter crew compartment. These were discussed previously in Section 4.2.2.

Table 5-8. EI Weight Differences Between the 7-Day and 30-Day Biomedicine/Biology COL

E.I. NO.	EQUIPMENT ITEM	E.I. WEIGHT, KG 30-DAYS	7-DAYS	DIFF.	RECOMMENDED REFURBISHMENT BETWEEN FLIGHTS
C6	AIR PARTICLE SAMPLER	2.7	2.6	0.1	REPLACE FILTERS
C188	AUTO. POTEN. ELECTROLYTE ANALYZER	12.7	9.1	3.6	REPLACE REAGENT & WASTE LIQUID CONTAINERS, CLEAN
C189	BLOOD SAMPLE PROCESSOR CENTRIFUGE	12.7	12.7	0	
C30A	CAGE, SMALL VERTEBRATES (8 REQD.)	21.5	18.4	3.0	REPLENISH FOOD, REPLACE URINE PAD & FILTER, CLEAN CAGE, REPLACE LIGHTS
C38	CAMERA, VIDEO, COLOR	7.7	7.7	0	
C36	CAMERA, 35MM	2	2.0	NEGL.	
C156	COUPLERS	2.4	2.4	0	
C55A	CREW MOBILITY AIDS	2.3	2.3	0	
C55B	CREW RESTRAINTS	4.0	4.0	0	
C192	DISPLAY, NUMERIC	2.0	2.0	0	
C167B	DRY STORAGE CONTAINER (ROOM TEMP)	1.0	0.5	0.5	CLEAN
C196	EQUIPMENT RESTRAINTS	0.5	0.5	0	
C80	FREEZER, GENERAL	7.0	7.0	0	
C81	FREEZER, LOW TEMPERATURE	7.0	7.0	0	
C103	HOLDING UNIT, SM. VERT.	13.6	13.6	0	CLEAN & REPLACE FILTER
C198	INCUBATOR, 37C (MINI)	5.0	5.0	0	
C200	KIT, ANIMAL PHYSIOLOGY	1.5	1.5	0	REPLACE CONSUMMABLES & REPACKAGE
C106A	KIT, CLEAN-UP	3.0	1.5	1.5	REPLACE KIT
C113	KIT, GENERAL TOOL	4.5	4.5	0	
C106	KIT, HEMATOLOGY	8.0	4.0	4.0	REPLACE CONSUMMABLES & REPACKAGE
C108	KIT, HISTOLOGY	3.0	1.0	2.0	" " " "
C110C	KIT, HUMAN PHYSIOLOGY	3.0	3.0	0	" " " "
C110	KIT, MICROBIOLOGY	6.0	2.0	4.0	" " " "
C114A	KIT, MICRODISSECTION	1.0	1.0	0	" " " "
C110B	KIT, VERTEBRATE MANAGEMENT	3.0	3.0	0	" " " "
C202	LAMP, PORTABLE HI INT. PHOTO	6.3	6.3	0	REPLACE BULB
C116	LOG BOOKS	1.0	0.5	0.5	
C91	MASS SPECTROMETER	11.3	11.3	0	REPLACE ADSORBENTS
C126	MICROSCOPE, COMPD	11.0	11.0	0	REPLACE LAMP
C126A	MICROSCOPE, DISSECTING	9.0	9.0	0	REPLACE LAMP
C203A	OCULOGYRAL ILLUSION BOX	0.2	0.2	0	
C132	OSCILLOSCOPE (BATTERY POWERED)	1.6	1.6	0	REPLACE BATTERY
C149G	RADIOISOTOPE TRACERS	0.3	0.3	0	REPLACE
C153	RECORDER, VOICE	1.0	1.0	NEGL.	REPLACE BATTERY
C83	REFRIGERATOR	5.0	5.0	0	CLEAN
C153B	SENSORS, MISCELLANEOUS	2.0	2.0	0	
C206	SHROUD, DEBRIS CONTAINMENT	4.5	4.5	0	CLEAN OR REPLACE
C165	STERILIZER, TOOL (BACTECINERATOR)	1.0	1.0	0	
C177	TEMPERATURE PROBES	0.3	0.3	0	
C180	TIMER, EVENT	0.2	0.2	0	
C48	VACUUM CLEANER	2.3	2.3	NEGL.	CLEAN & REPLACE WASTE RECEPTACLE
C193	VENTILATION UNIT, SMALL VERT.	9.5	9.5	0	REPLACE FILTERS
C181G	WASTE STORAGE CONTAINER	1.0	1.0	0	CLEAN
C174	WATER TANK, ORGANISM (WET WT.)	12.6	4.6	8.0	CLEAN, FLUSH & REFILL
C208	WIRE AND CABLE	2.0	2.0	0	
C209	WORK SURFACE, AIRFLOW	5.0	5.0	0	CLEAN & REPLACE FILTER
	TOTALS	224.2 (494 LB)	196.9 (434 LB)	27.2 (60 LB)	

Table 5-9. EI Weight Differences Between the 7-Day and 30-Day LSPS and MSI COLs

E.I. NO.	EQUIPMENT ITEM	E.I. WEIGHT, KG 30-DAYS	7-DAYS	DIFF.	RECOMMENDED REFURBISHMENT BETWEEN FLIGHTS
	<u>LSPS COL</u>				
C32	CAMERA, CINE	5.0	5.0	0	
C37	CAMERA, VIDEO, BLACK/WHITE	4.4	4.4	0	
C36	CAMERA, 35MM	2.0	2.0	NEGL.	
C55A	CREW MOBILITY AIDS	2.3	2.3	0	
C55B	CREW RESTRAINTS	4.0	4.0	0	
C192	DISPLAY, NUMERIC	2.0	2.0	0	
C196	EQUIPMENT RESTRAINTS	0.5	0.5	0	
C76C	FILM, CINE	6.5	2.2	4.3	
C167C	FILM CABINET	9.1	9.1	0	
C197	FLOWMETERS	2.0	2.0	0	
C89	GAS CHROMATOGRAPH	10.0	10.0	NEGL.	REPLACE COLUMNS, REFILL WITH CARRIER GAS
C93A	GAS SUPPLY VESSELS	11.5	8.1	3.4	REFILL
C199	INFRARED GAS ANALYZER	11.3	11.3	0	
C201	KIT, CHEMICAL SAMPLING	4.5	1.5	3.0	REPLACE CONSUMMABLES & REPACKAGE
C106A	KIT, CLEAN-UP	3.0	1.5	1.5	REPLACE KIT
C113	KIT, GENERAL TOOL	4.5	4.5	0	
C202	LAMP, PORTABLE HI INT. PHOTO	6.3	6.3	0	REPLACE BULB
C203	LIQUID TANK (WET WT.)	16.5	9.0	7.5	CLEAN & REFILL
C116	LOG BOOKS	1.0	0.5	0.5	
C122	MASS MEASUREMENT DEVICE	15.9	15.9	0	
C91	MASS SPECTROMETER	11.3	11.3	0	REPLACE SORBENTS
C204	PLUMBING	10.0	10.0	0	FLUSH & CLEAN
C205	RECORDER, STRIP CHART (BATT. POW.)	14.0	12.5	1.5	REPLACE BATTERY
C153	RECORDER, VOICE	1.0	1.0	NEGL.	REPLACE BATTERY
C83	REFRIGERATOR	5.0	5.0	0	CLEAN
C153B	SENSORS, MISCELLANEOUS	2.0	2.0	0	
C155B	SHROUD, ENVIRONMENTAL	4.5	4.5	0	
C177	TEMPERATURE PROBES	0.3	0.3	0	
C180	TIMER, EVENT	0.2	0.2	0	
C48	VACUUM CLEANER	2.3	2.3	NEGL.	CLEAN & REPLACE WASTE RECEPTACLE
C118I	VACUUM MANIFOLD	9.1	9.1	0	
C185	VOLT-OHMMETER (VOM), (BATT. POW.)	2.0	2.0	0	REPLACE BATTERIES
C181G	WASTE STORAGE CONTAINER	1.0	1.0	0	CLEAN
	TOTALS	185.0 (408 LB)	163.3 (360 LB)	21.7 (48 LB)	
	<u>MSI COL</u>				
C38	CAMERA, VIDEO, COLOR	7.7	7.7	0	
C36	CAMERA, 35MM	2.0	2.0	0	
C190	CAMERA MOUNTS	3.0	3.0	0	
C191	CAMERA,TIMER, VIDEO	4.0	4.0	0	
C55A	CREW MOBILITY AIDS	2.3	2.3	0	
C55B	CREW RESTRAINTS	4.0	4.0	0	
C196	EQUIPMENT RESTRAINTS	0.5	0.5	0	
C113	KIT, GENERAL TOOL	4.5	4.5	0	
C202	LAMP, PORTABLE HI INT. PHOTO	6.3	6.3	0	REPLACE BULB
C116	LOG BOOKS	1.0	0.5	0.5	
C126B	MICROPHONE	0.5	0.5	0	
C180	TIMER, EVENT	0.2	0.2	0	
C176	VIDEO TAPE	15.0	5.0	10	
C207	VIDEO TAPE RECORDER	22.3	22.3	0	
	TOTALS	73.3 (162 LB)	62.8 (138 LB)	10.5 (23 LB)	

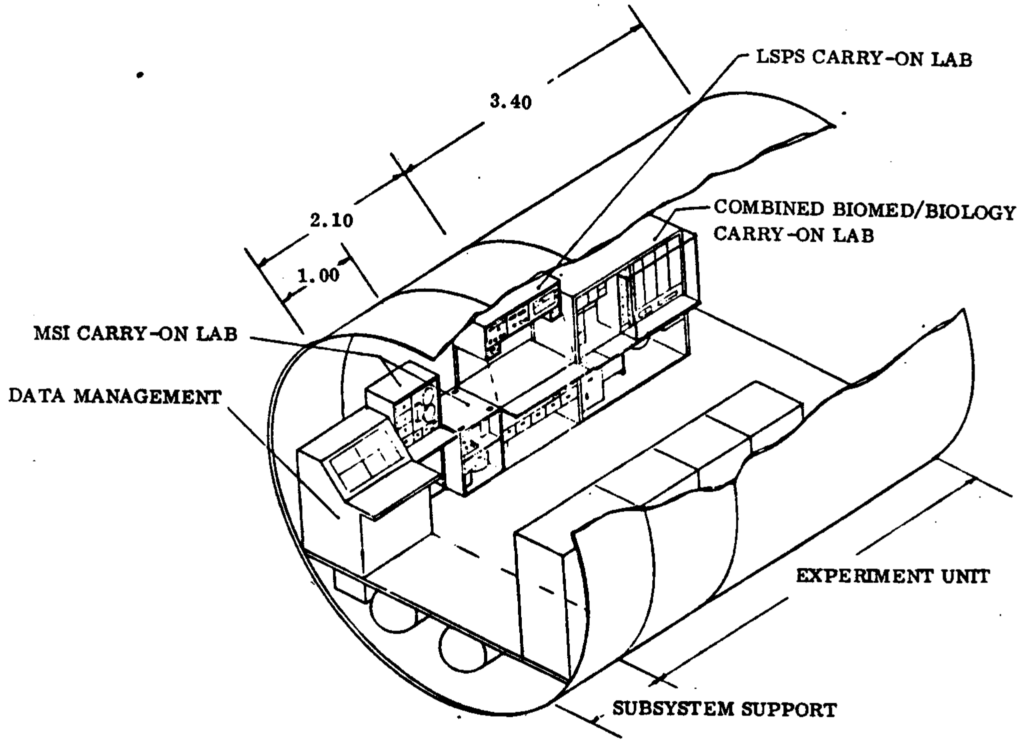


Figure 5-3. Category A COLs Integrated Within the Spacelab

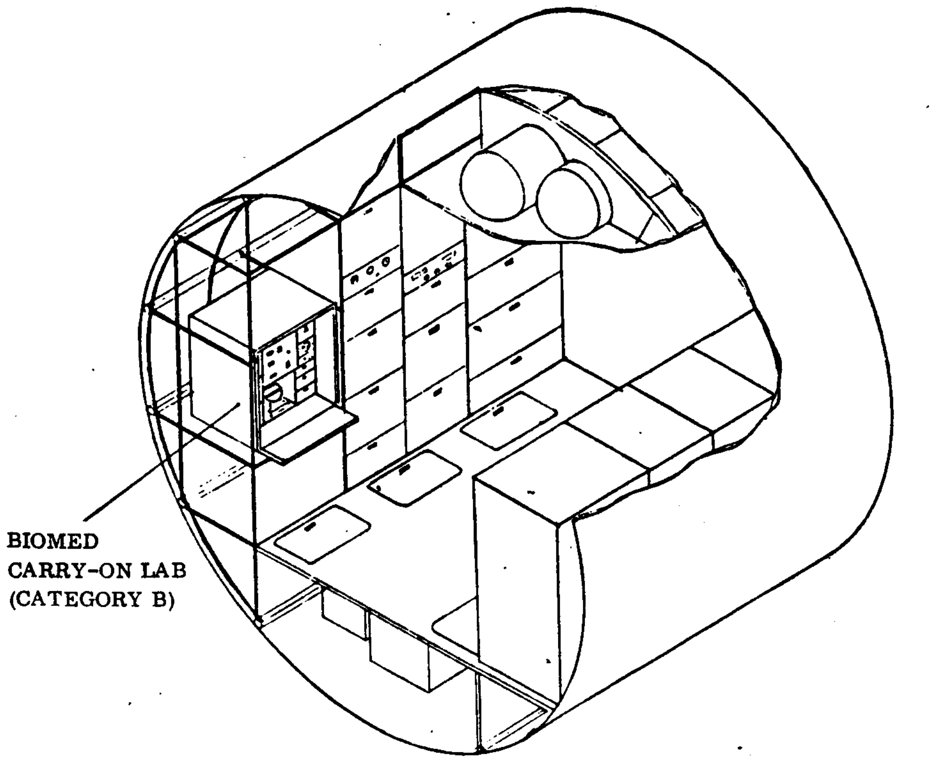


Figure 5-4. Category B Biomedical COL Integrated Within the Spacelab

5.5 INTERFACE SUMMARIES

Overall pertinent interface data for the final COLs is summarized in Tables 5-10 through 5-14. Most data presented in these tables is self-explanatory or has been discussed previously.

Table 5-10. Summary of Category A Biomedicine/Biology COL Interfaces

INTERFACE AREA	REQUIREMENTS
A. SHUTTLE	A. CATEGORY A LABS ARE NOT LOCATED IN THE SHUTTLE CREW COMPARTMENT.
B. SPACELAB	B. COL IS LOCATED IN PRESSURIZED AREA TAKING 1.52 METERS OF WALL SPACE. APPROXIMATE ENVELOPE IS 1.52 WIDE × 1.55 HIGH × 0.61 DEEP.
C. STRUCTURAL	C. CONCEPTUAL DESIGN INDICATES PORTABLE CONSOLE COMPRISED OF 4 MODULES TOTALING 261 KG. FLOOR & BACK STRUCTURAL ATTACHMENTS REQUIRED DURING LAUNCH-ORBIT-REENTRY.
D. ELECTRICAL POWER (ENERGY)	D. PEAK POWER: 1099 WATTS - AVERAGE POWER: 756 WATTS FOR 2 HOUR OPERATION. ENERGY CONSUMPTION: 6807 WATT-HRS/DAY. FOR DETAILS, SEE TABLE 5-1.
E. CREW ECS/LSS	E. DURING MAN-SURROGATE MISSIONS, THE VERTEBRATE HOLDING UNIT TAKES IN 623 DM^3 (22 CFM) OF AMBIENT SPACELAB AIR & DISCHARGES THE SAME AMOUNT BACK INTO THE SPACELAB AFTER FILTERING TO REMOVE PARTICULATE MATTER & ODORS.
F. THERMAL CONTROL	F. THE AVERAGE HEAT REJECTED TO THE AIR, BASED UPON ELECTRICAL POWER, IS 132 WATTS DURING 22 HOUR STANDBY AND 356 WATTS DURING THE 2 HOUR USE PERIOD. HEAT REJECTION TO THE COOLANT LOOP IS 400 WATTS FOR 8 HOURS EACH DAY. THE COOLANT IS REQUIRED FOR THE LOW TEMPERATURE FREEZER AT 150 KG/HR AT 7°C.
G. COMMAND & DATA MANAGEMENT SUBSYSTEM (CDMS)	G. THE SPACELAB PROVIDES ALL THE CDMS SUPPORT NEEDED FOR THE CARRY-ON LAB. ESTIMATED CONTINUOUS DATA BIT RATE IS 7,042 BPS, DOWNLINK REQUIREMENTS ARE 6177 KBITS/DAY. FOR ADDITIONAL DETAILS, SEE TABLE 5-6.
H. CONSUMMABLES	H. THE CONSUMMABLES ARE BASED UPON A 30-DAY MISSION. THE VERTEBRATES REQUIRE FOOD, WATER, FILTERS, & WASTE PADS. THE ESTIMATED WEIGHT IS 14 KG. DURING REFURBISHMENT, THE VARIOUS KITS WILL REQUIRE REPLACEMENT OF MATERIAL SUCH AS FLUIDS & EXPENDABLE STERILE ITEMS ESTIMATED AT 15 KG. CALIBRATION FLUIDS & REAGENTS ARE REQUIRED FOR THE ELECTROLYTE ANALYZER & ARE ESTIMATED AT 4.7 KG. SEVERAL OTHER MINOR CONSUMMABLES PLUS THE ABOVE BRING THE TOTAL EXPENDABLES FOR THIS COL TO APPROXIMATELY 35 KG FOR 30 DAYS.
I. OPERATIONAL/MISSION	I. THIS COL REQUIRES THE SPACELAB CREW FOR OPERATION, BOTH IN THE MODE OF OBSERVER AND SUBJECT. BECAUSE OF THE LIVE ORGANISMS ON BOARD THIS LABORATORY, GROUND BASED SUPPORT REQUIREMENTS AT THE LAUNCH AND LANDING FACILITY INCLUDE ORGANISM HOUSING, ECS/LSS, DATA ACQUISITION & ELECTRICAL POWER. A BIOLOGICAL EXPERIMENT SUPPORT AND TRANSFER UNIT (BEST) IS AN INTEGRAL PART OF THIS SUPPORT REQUIREMENT (SEE REFERENCE 1 FOR "BEST" DETAILS). THE INTERACTION OF COMPETING RESEARCH PAYLOADS FOR ON-ORBIT POWER, DATA HANDLING, THERMAL CONTROL, ETC., MUST BE DETERMINED ON AN INDIVIDUAL BASIS; THEREFORE, NO STATEMENTS AS TO COMPATIBILITY CAN BE MADE AT THIS TIME.

Table 5-11. Category B Biomedicine COL Interfaces

INTERFACE AREA	REQUIREMENTS
A. SHUTTLE	A. THIS COL IS PRIMARILY INTENDED FOR INSTALLATIONS IN THE SPACELAB. HOWEVER, SHUTTLE FLIGHT DECK INSTALLATION IS AN ALTERNATIVE OPTION. BY REMOVAL OF 6 STOWAGE MODULES 36×43×51 CM (14×17×20") IN A 2 MODULE WIDE BY 3 MODULE HIGH CONFIGURATION, THE COL CAN BE ACCOMMODATED.
B. SPACELAB	B. LOCATED IN THE PRESSURIZED AREA TAKING 0.91 METER OF WALL SPACE. APPROXIMATE ENVELOPE IS 0.91 M WIDE × 1.55 M HIGH × 0.56 M DEEP.
C. STRUCTURAL	C. CONCEPTUAL DESIGN INDICATES A SINGLE PORTABLE MODULE. THIS MODULE IS MOUNTED 0.76 METER ABOVE THE FLOOR LEVEL. COL WEIGHS 85 KG. ATTACHMENT AT WALL MOUNTING STRUCTURE REQUIRED DURING LAUNCH, ORBIT, & RE-ENTRY.
D. ELECTRICAL POWER (ENERGY)	D. PEAK POWER IS 634 WATTS. AVERAGE POWER IS 526 WATTS DURING THE 2 HOUR USE PERIOD. ENERGY CONSUMPTION IS 3865 WATT HOURS/DAY. FOR ADDITIONAL DETAILS, SEE TABLE 5-2.
E. CREW ECS/LSS	E. NO COL REQUIREMENT.
F. THERMAL CONTROL	F. THE AVERAGE HEAT REJECTION, BASED UPON THE ELECTRICAL POWER, IS 126 WATTS TO THE AIR DURING THE 2 HOURS OF RESEARCH OPERATION AND 19 WATTS DURING STANDBY. 400 WATTS ARE REJECTED TO THE COOLANT LOOP FOR 8 HOURS EACH DAY. THE COOLANT IS REQUIRED FOR THE LOW TEMPERATURE FREEZER AND IS 150 KG/HR AT 7°C.
G. COMMAND & DATA MANAGEMENT SUBSYSTEM (CDMS)	G. THE SPACELAB PROVIDES ALL THE CDMS SUPPORT NEEDED FOR THE CARRY-ON LAB. THE CATEGORY B REQUIREMENTS ARE BASED UPON THE COUPLERS USED FOR THE ECG AND VCG. ESTIMATED DAILY RATE IS 75,600 KBITS. THE DOWNLINK REQUIREMENTS ARE 3780 KBITS/DAY.
H. CONSUMMABLES	H. THE CONSUMMABLES ARE BASED UPON A 30-DAY MISSION. DURING REFURBISHMENT BETWEEN FLIGHTS, THE VARIOUS KITS WILL REQUIRE CHEMICALS, FLUIDS, REPLACEABLE STERILE ITEMS ESTIMATED AT 5.2 KG. CALIBRATION FLUIDS FOR THE BLOOD ELECTROLYTE ANALYZER ARE ESTIMATED AT 4.7 KG. TOTAL EXPENDABLE WEIGHT IS APPROXIMATELY 10 KG PER 30 DAYS.
I. OPERATIONAL/MISSION	I. THIS COL REQUIRES THE CREW FOR OPERATION IN BOTH THE OBSERVER AND SUBJECT MODES. THE INTERACTION OF COMPETING RESEARCH PAYLOADS FOR SPACELAB FACILITY SUPPORT MUST BE EVALUATED ON AN INDIVIDUAL BASIS. THEREFORE, NO STATEMENT OF COMPATIBILITY CAN BE MADE AT THIS TIME.

Table 5-12. Category C Biomedical COL Interfaces (Includes C_1, C_2, and C_3 Versions)

INTERFACE AREA	REQUIREMENTS
A. SHUTTLE	A. DESIGNED SPECIFICALLY TO BE COMPATIBLE WITH THE FLIGHT DECK STOWAGE. ALL EQUIPMENT IS SIZED TO FIT A 36×43×51 CM (14×17×20") MODULE. ALL CATEGORY C VERSIONS.
B. SPACELAB	B. NO COL REQUIREMENT.
C. STRUCTURAL	C. COL C_1 CONCEPT IS CONTAINED WITHIN 3 OF THE 36×43×51 CM STOWAGE MODULES. COL C_2 " " " " 2 " " " " " " COL C_3 " " " " 1 " " " " " "
D. ELECTRICAL POWER (ENERGY)	D. C_1 CONCEPT PEAK POWER IS 100 WATTS. AVERAGE 25 WATTS FOR 2 HOURS' OPERATION, TOTAL ENERGY CONSUMPTION 50 W-HR/DAY. C_2 CONCEPT PEAK POWER IS 500 WATTS, AVERAGE 425 WATTS FOR 2 HOURS' OPERATION, TOTAL ENERGY CONSUMPTION 4850 W-HR/DAY. C_3 CONCEPT PEAK POWER IS 60 WATTS, AVERAGE 66 WATTS FOR 2 HOURS' OPERATION, TOTAL ENERGY CONSUMPTION 432 W-HR/DAY.
E. CREW ECS/LSS	E. NO COL REQUIREMENT.
F. THERMAL CONTROL	F. C_1 CONCEPT AVERAGE HEAT REJECTION BASED UPON THE ELECTRICAL POWER IS 25 WATTS TO THE AIR DURING THE ESTIMATED 2 HOURS' OPERATION. C_2 CONCEPT AVERAGE HEAT REJECTION BASED UPON THE ELECTRICAL POWER IS 25 WATTS TO THE AIR & 400 WATTS TO A COOLANT. THE COOLANT FLOW IS 150 KG/HR AT 7°C. THE 400 WATTS IS FOR THE LOW TEMPERATURE FREEZER (-70°C). HEAT REJECTION TO THE AIR RATHER THAN A COOLANT CAN BE ACCOMPLISHED BY INCREASING THE FREEZER ON TIME FROM THE NOMINAL 8 HOUR DUTY CYCLE TO APPROXIMATELY 12 HOURS. C_3 CONCEPT AVERAGE HEAT REJECTION BASED UPON THE ELECTRICAL POWER IS 66 WATTS TO THE AIR DURING THE ESTIMATED 2 HOURS' OPERATION.
G. COMMAND & DATA MANAGEMENT SUBSYSTEM	G. ONLY THE C_3 CONCEPT HAS ANY CDMS REQUIREMENT. THIS REQUIREMENT IS BASED UPON THE COUPLERS USED FOR THE ECG & VCG. ESTIMATED DAILY RATE IS 75,600 KBITS, THE DAILY DOWNLINK REQUIREMENT IS 3,780 KBITS.
H. CONSUMMABLES	H. ALL THREE COL CONCEPTS WILL REQUIRE REFURBISHMENT AFTER EACH MISSION. THIS WILL INCLUDE CALIBRATION GASES & FLUIDS FOR CONCEPTS C_1 & C_2 & KIT REPLACEMENT ITEMS FOR ALL THREE CONCEPTS. THE ESTIMATED WEIGHT FOR EACH CONCEPT — C_1: 9 KG, C_2: 2 KG, C_3: 2 KG — BASED ON 30 DAYS.
I. OPERATIONAL/MISSION	I. THESE COL CONCEPTS REQUIRE THE CREW FOR OPERATION IN BOTH THE OBSERVER AND SUBJECT MODES. MINIMAL IMPACT IS EXPECTED BETWEEN THESE CONCEPTS AND OTHER COMPETING RESEARCH PAYLOADS. THESE THREE COL'S, IF COMBINED INTO 100 OR 150 POUND PAYLOADS, CAN MATERIALLY ENHANCE THE CAPABILITY IN THE PRIORITY BIOMED AREAS.

Table 5-13. Category A Man/System Integration COL Interfaces

INTERFACE AREA	REQUIREMENTS
A. SHUTTLE	A. CATEGORY A LABS ARE NOT LOCATED IN THE SHUTTLE CREW COMPARTMENT.
B. SPACELAB	B. LOCATED IN THE PRESSURIZED AREA TAKING 1.27 METERS OF WALL SPACE. APPROXIMATE ENVELOPE IS 1.27 WIDE × 1.40 HIGH × 0.61 DEEP.
C. STRUCTURAL	C. CONCEPTUAL DESIGN INDICATES A PORTABLE CONSOLE & STORAGE RACK IN 3 MODULES. COL WEIGHS 87.7 KG PLUS ADDITIONAL WEIGHT FOR EXPERIMENT SPECIFIC EQUIPMENT. CONSOLE ATTACHMENT AT THE FLOOR & BACK REQUIRED DURING LAUNCH, ORBIT & REENTRY.
D. ELECTRICAL POWER (ENERGY)	D. PEAK POWER:309 WATTS. AVERAGE: 78 WATTS FOR 2 HOUR OPERATION. ENERGY CONSUMPTION 155 WATT-HRS/DAY. FOR DETAILS, SEE TABLE 5-4.
E. CREW ECS/LSS	E. NO COL REQUIREMENT.
F. THERMAL CONTROL	F. THE AVERAGE HEAT REJECTION BASED UPON ELECTRICAL POWER IS 78 WATTS FOR THE 2 HOUR OPERATION PERIOD. THERE IS NO STANDBY HEAT REJECTION REQUIREMENT.
G. COMMAND & DATA MANAGEMENT SUB-SYSTEM (CDMS)	G. THE SPACELAB PROVIDES ALL THE CDMS SUPPORT NEEDED FOR THE CARRY-ON LAB. THE TOTAL DAILY DATA GENERATED IS 40 KBITS. THERE IS NO DIGITAL DOWNLINK REQUIREMENT. VIDEO TAPE IS PART OF THE COL & IS USED FOR POST FLIGHT ANALYSIS.
H. CONSUMMABLES	H. THE MAJOR CONSUMMABLE FOR THIS COL IS THE VIDEO TAPE. TOTAL WEIGHT IS APPROXIMATELY 11 KG.
I. OPERATIONAL/MISSION	I. THIS COL REQUIRES THE CREW FOR OPERATION IN BOTH THE OBSERVER & SUB-JECT MODES. THE DEMANDS FOR THIS COL ARE RELATIVELY SMALL & COULD PROBABLY BE INCLUDED IN MOST RESEARCH PAYLOADS. DETAILS, HOWEVER, WOULD HAVE TO BE WORKED OUT ON AN INDIVIDUAL BASIS.

Table 5-14. Category A LSPS COL Interfaces

INTERFACE AREA	REQUIREMENTS
A. SHUTTLE	A. CATEGORY A LABS ARE NOT LOCATED IN SHUTTLE CREW COMPARTMENT.
B. SPACELAB.	B. LOCATED IN PRESSURIZED AREA TAKING 1.07 METERS OF WALL SPACE. APPROXIMATE TOTAL ENVELOPE VOLUME OF COL IN METERS IS 1.07 WIDE × 1.68 HIGH × 0.61 DEEP.
C. STRUCTURAL	C. CONCEPTUAL DESIGN INDICATES TWO PORTABLE MODULES TOTALING 198 KG EXCLUSIVE OF EXPERIMENT SPECIFIC EQUIPMENT. CONSOLE ATTACHMENT AT THE FLOOR AND BACK REQUIRED DURING LAUNCH, ORBIT & RE-ENTRY.
D. ELECTRICAL POWER (ENERGY)	D. PEAK POWER: 320 WATTS. AVERAGE POWER: 152 WATTS FOR 2 HOUR OPERATION. ENERGY CONSUMPTION: 2330 WATT HRS/DAY. THIS POWER IS EXCLUSIVE OF EXPERIMENT SPECIFIC EQUIPMENT. FOR COL DETAILS, SEE TABLE 5-4.
E. CREW ECS/LSS	E. THIS INTERFACE IS EXPERIMENT SPECIFIC BUT ANY EFFECTS THAT EXPERIMENTAL TEST APPARATUS HAVE ON THE SPACELAB CREW ECS/LSS ARE EXPECTED TO BE MINOR.
F. THERMAL CONTROL	F. THE AVERAGE HEAT REJECTION, BASED ON ELECTRICAL POWER, IS 152 WATTS TO THE CABIN AIR DURING THE 2 HOURS OF RESEARCH OPERATION, EXCLUSIVE OF EXPERIMENT SPECIFIC EQUIPMENT. STANDBY HEAT REJECTION IS 92 WATTS.
G. COMMAND & DATA MANAGEMENT SUBSYSTEM (CDMS)	G. THE SPACELAB PROVIDES ALL CDMS SUPPORT. ESTIMATED DATA RATES, EXCLUSIVE OF EXPERIMENT SPECIFIC EQUIPMENT, ARE: (1) 66 BPS CONTINUOUS DATA, (2) 6159 KBITS/DAY TOTAL DATA, AND (3) 15,000 BITS/DAY DOWNLINK REQUIREMENT.
H. CONSUMMABLES	H. THE CONSUMMABLES ARE BASED ON A 30-DAY MISSION. MAJOR CONSUMMABLES ARE LIQUIDS & GASES REQUIRED FOR EXPERIMENT SUPPORT, KIT ITEMS AND FILM. THE TOTAL WEIGHT IS APPROXIMATELY 28 KG FOR 30 DAYS.
I. OPERATIONAL/MISSION	I. THE LSPS COLS MAY REQUIRE THE CREW TO ACT AS SUBJECTS & ALSO FOR PURPOSES OF MONITORING & CONTROLLING THE EXPERIMENTS. THE EXPERIMENTS REQUIRING BOTH TYPES OF ACTIVITY WILL GENERALLY REQUIRE TWO CREWMAN SIMULTANEOUSLY. EXPERIMENTS NEEDING ONLY CREW MONITORING & CONTROL WILL USUALLY REQUIRE ONLY ONE MAN. IN ALL CASES, AN AVERAGE OPERATIONAL PERIOD OF 2 HOURS PER DAY HAS BEEN ASSUMED. EXPERIMENT START-UP AND SHUT-DOWN WILL USUALLY BE DONE IN ORBIT, & WILL REQUIRE EXTRA CREW TIME DURING THESE PERIODS, THE AMOUNT DEPENDING UPON THE SPECIFIC EXPERIMENT. NO CREW ATTENTION (REMOTE MONITORING) IS ANTICIPATED DURING LAUNCH AND RE-ENTRY. THE INTERACTION OF COMPETING RESEARCH PAYLOADS FOR POWER, DMS, THERMAL CONTROL, ETC., MUST BE WEIGHED ON AN INDIVIDUAL BASIS; THEREFORE, NO STATEMENTS AS TO COMPATIBILITY CAN BE MADE AT THIS TIME.

SECTION 6

LABORATORY SCHEDULES AND COST ANALYSIS

6.1 SUMMARY

This section documents the results of COL scheduling and costing activities and includes a discussion of the Low-Cost methodology used to establish individual COL EI costs. This approach allows consideration of equipment that is commercial off-the-shelf, modified commercial, laboratory prototypes, etc., which significantly lower the program costs. Costs generated include estimates for the nonrecurring development, recurring production, and reucrring operations costs. These estimates do not include such major elements as the Space Shuttle vehicle, Spacelab, or principal investigator costs.

A summary of the COL costs are shown in Table 6-1. A total of seven COL configurations were estimated, based on independent development. In addition, two sequential development cases were costed. The costs reported here are commensurate with the design and schedule definition available, with the understanding that the estimates are for budgetary and planning purposes.

Table 6-1. COL Cost Summary

CARRY-ON LABS	INDEPENDENT DEVELOPMENT COSTS NON-REC	REC-PROD	TOTAL
CAT A - BIOMED/BIOLOGY	$5023K	$586K	$5609K[1]
CAT A - MSI	437	139	576
CAT A - LS/PS	1737	324	2061
CAT B - BIOMEDICINE	1142	138	1208
CAT C1 - BIOMEDICINE	194	84	278
CAT C2 - BIOMEDICINE	179	22	201
CAT C3 - BIOMEDICINE	149	23	172

CARRY-ON LABS	SEQUENTIAL DEVELOPMENT COSTS NON-REC	REC-PROD	TOTAL
EXAMPLE A			
1. DEVELOP CAT C1, C2, & C3	$522K	$129K	$651 K
2. DEVELOP CAT B - BIOMEDICINE	894	138	1032
3. DEVELOP CAT A - BIOMED/BIOL.	4347	586	4933 Σ$6616K ($7540K)[2]
EXAMPLE B			
1. DEVELOP CAT A - BIOMED/BIOL.	$5023K	$586K	$5609K
2. DEVELOP CAT B - BIOMEDICINE	587	138	725 Σ$6334K ($6889K)[2]

[1] RECURRING OPERATIONS = $613K/YR @ 2 FLIGHTS/YR. (12 YEAR PROGRAM COST - $5609K + $7356K = $12,965K)

[2] TOTAL BASED ON INDEPENDENT DEVELOPMENT

6.2 LABORATORY DEVELOPMENT SCHEDULES

The COL development schedule and fiscal funding (Figure 6-1) were generated for the Category A biomedicine/biology laboratory. It was assumed that the other COL concepts, since they were less complex, did not represent a controlling schedule restraint.

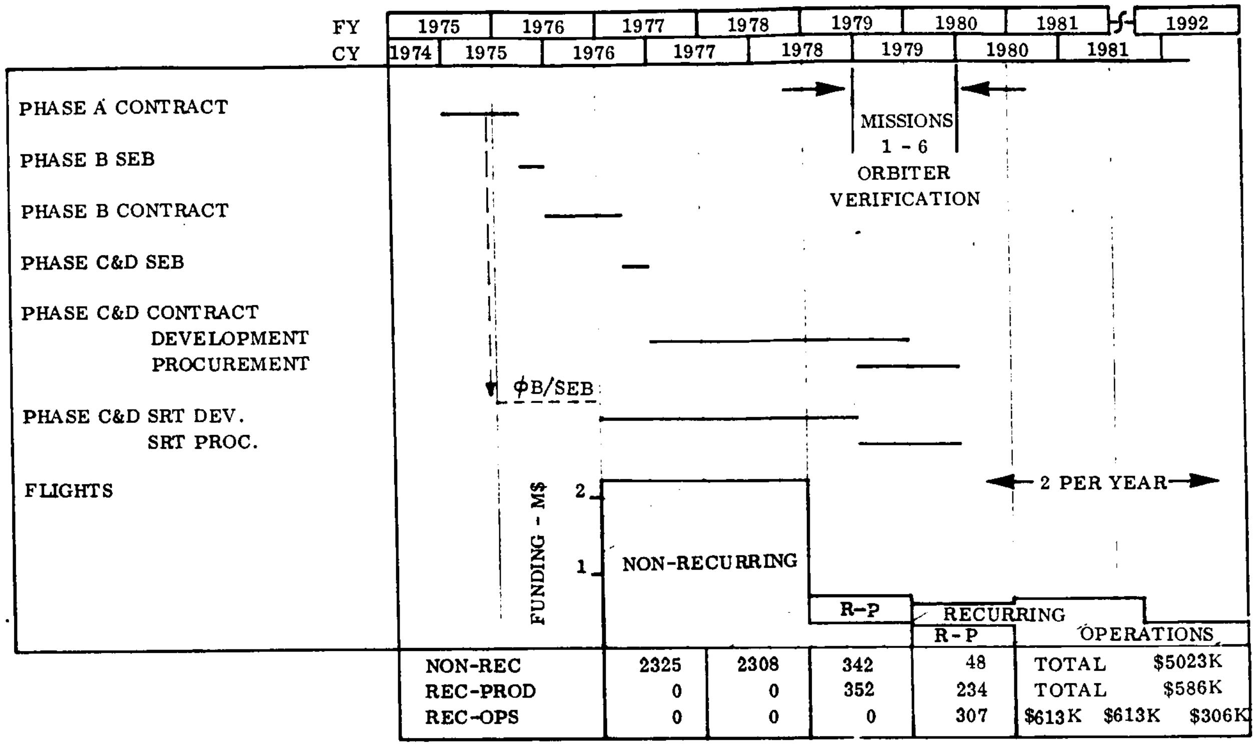


Figure 6-1. COL Development Schedule and Funding

The development is paced initially by the first flight date of April 1980, as specified in Reference 3. Subsequently, the development schedule is paced by the development of each EI in the COL. Two classes of EIs were identified.

Items under the category of supporting research and technology (SRT), which include the common holding unit and its cages, are one class. These items exhibit the highest development risk and require a 2.5 year development program plus extensive evaluation in the principal investigators' laboratories. It was assumed that the SRT requirements and planning can be established beofre the end of the COL Phase A study to enable initiation of SRT Phase B activity. This approach satisfies the time requirements of SRT development and evaluation prior to the flight date.

The other EI class includes the remaining EIs (all that are not SRT). Development time of each EI was estimated by Convair and/or vendors, and is based on the complexity of the EI and the difficulty of its manufacture. The longest EI development times are 2.5 years, and this time span was selected for the development of all non-SRT EIs. The procurement phase is initiated six months before completion of the development phase for all non-SRT EIs so that about 6 months is available for integration, installation, and checkout of the COL in the Spacelab. Minimum risk is expected by initiating procurement prior to completion of the development phase, since the last development task represent some individual EI qualification tests and the COL system tests. Very few changes that would impact production are expected during this phase of development.

6.3 COST ANALYSIS

An overview of the cost analysis approach is shown in Figure 6-2. EIs selected for the conceptual designs presented in Section 4 provided the basis for this cost analysis. Guidelines reflecting the NASA low-cost philosophy as described in References 4, 5, and 6 were used to develop the program cost elements. The basic costing methodology was developed for both the large dedicated life sciences laboratory and the COL. This costing methodology is detailed in Section 6.3.2.

6.3.1 <u>COST ANALYSIS GROUND RULES AND ASSUMPTIONS</u>. The following general ground rules were used in the cost estimating.

a. Costs are estimated in 1974 dollars and reported by government fiscal year.

b. Only Phase C and D and recurring operations are costed.

c. GFE nonrecurring costs are excluded. (These costs, however, are used as inputs for cost elements estimated on the basis of hardware costs, etc.)

d. Supporting research and technology (SRT) items are included in the costs.

e. All EIs are included under prime development category because subcontract items have not been identified at this time.

f. All General and administration (G&A) and other overheads except management and administration are included in each of the EI cost elements.

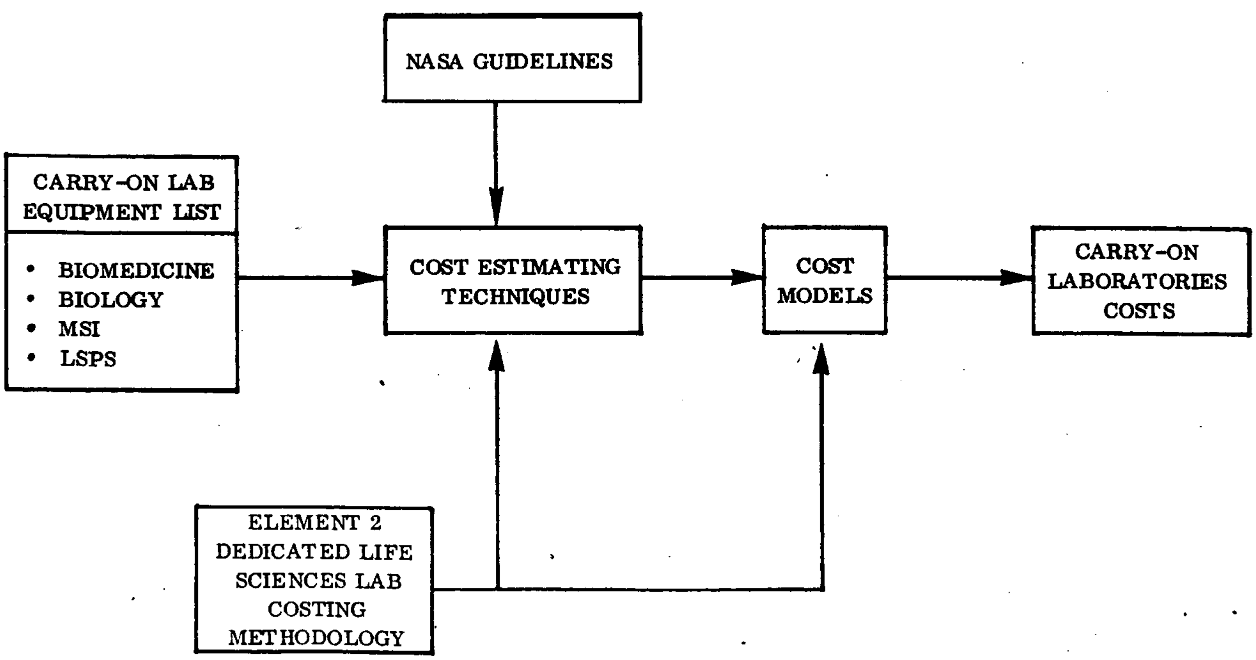


Figure 6-2. Cost Analysis Overview

g. The cost methodology selected provides costs commensurate with early payload definition information. Cost estimates are for preliminary budgetary and planning purposes.

h. No EIs were costed for the COL systems test (WBS Level 3). It was assumed that test specimens from individual qualification tests are available. Similarly, no EI costs were included for the Spacelab tests, but a refurbishment of 10 percent of recurring production costs (for 50 percent of the items) was included in the COL systems test to refurbish the equipment for the Spacelab test (WBS Level 2).

i. A 25 percent factor was added to vendor-purchased unit costs to account for prime contractor offsite procurement inspection, receiving inspection, and G&A costs.

j. For certain commercial equipment that requires minimum modification, development units were not included and any development tasks required are accomplished on the production unit.

The COL cost estimates based on these ground rules are further defined by the included and excluded items summarized in Table 6-2.

Table 6-2. Summary of Cost Elements

INCLUDED ITEMS	EXCLUDED ITEMS
NON-RECURRING DEVELOPMENT	
- DESIGN & DEVELOPMENT	NASA INTERNAL MANAGEMENT
- QUALITY ASSURANCE & RELIABILITY	PRINCIPAL INVESTIGATOR SUPPORT
- SYSTEM ENGINEERING	
- MISSION ANALYSIS	
- COL SYSTEMS TEST	EXPERIMENT SPECIFIC EQUIPMENT
- INTEGRATED SPACELAB TEST	
- INTEGRATION	GROUND-BASED LAB ARTICLES FOR CONTROL EXPERIMENTS
- GSE	
- INITIAL SPARES	TRAINING ARTICLES
RECURRING PRODUCTION	BIOEXPERIMENT SUPPORT & TRANSFER UNITS
- MANUFACTURE	BACKUP LABS
- QUALITY CONTROL	
- ACCEPTANCE TEST	GROUND MOCKUP
- SUSTAINING ENGINEERING	
	DEDICATED SPACELAB COST
RECURRING OPERATIONS	
- CONSUMPTION SPARES	SPACE SHUTTLE USER CHARGES
- REFURBISHMENT	
- LAUNCH OPERATIONS	PHASE A & B COSTS
- MISSION OPERATIONS	
GENERAL AND ADMINISTRATIVE	FLIGHT CREW COSTS
MANAGEMENT & ADMINISTRATION	GROWTH OR CONTINGENCY COSTS
FEE	FACILITIES COSTS

6.3.2 COST METHODOLOGY AND RATIONALE. A cost model using a WBS, including categories of hardware, services, and other cost tasks, was developed for the COL. The WBS, including Levels 1, 2, and 3 is shown in Table 6-3.

6.3.2.1 Cost Model. The cost model includes a set of individual EI cost estimating relationships (CERs), cost factors, or point estimates. The model also establishes a mathematical procedure for proper accumulation of the individual elements together with the overall program or mission factors (where defined) such as operational lifetime, number of launches, etc. It organizes the procedures for determining all individual cost "pieces" making up the total COL program cost.

The model derived an equipment unit hardware cost, which was employed where necessary during the derivation of nonrecurring (development) and recurring (production and operational) costs. These costs were then accumulated to provide the required total program cost. The individual equipment cost methodology and the application of the different item factors and their application are discussed in the following paragraphs.

Cost methodology for the individual EIs in each COL was tailored to obtain the highest confidence cost estimate with the information available. Table 6-4 shows the six methods of costing used and the percentage of the items included in each category.

A significant portion (33 percent) of the items was costed using CERs developed by the Space Shuttle Payload Development Activity (SSPDA) (Reference 7) for low-cost Spacelab payloads. A typical example of a cost data backup sheet is shown in Figure 6-3.

The SSPDA CERs were generated for general type of experiment equipment. These CERs were further refined with complexity factors for all EIs. Sources for the CERs include historical data, mission equipment studies, vendor contact, commercial catalogs, and inhouse experiment programs. The amount of applicable historical data was sparse. As a result, a wide variety of cost data was collected from manned and unmanned spacecraft programs, aircraft and balloon programs, and commercial laboratory equipment to augment the data base. The data was displayed on a cost-versus-weight graph and technological families identified. Log-linear CERs were then derived using standard curve-fitting techniques with weight as the driving parameter. SSPDA CERs were used to estimate costs where no higher confidence method was available. In some cases, SSPDA CER costs were reduced to account for savings expected because existing commercial equipment can be modified to meet the requirements.

The second highest percentage of items was estimated based on unofficial Skylab cost information. This data was obtained by contacting cognizant technical and management personnel at NASA. The majority of the items included were kits (17 percent), whose costs were estimated based on Skylab experience with the inflight medical support system kit development.

Table 6-3. COL Cost Work Breakdown Structure

	NR	R-P	R-O
LEVEL 1 - LABORATORY PROJECT			
Laboratory Hardware	x	x	x
Spacelab		x	x
LEVEL 2 - LABORATORY HARDWARE			
CARRY-ON LAB (see Level 3)	x	x	
*SPARES			
Initial Spares	x		
Consumption Spares			x
*INTEGRATED SPACELAB TEST	x		
*SYSTEM ENGR'G/SYSTEM INTEG			
COL - Spacelab	x		
*FLIGHT OPERATIONS			
Refurbishment			x
MGMT & ADMIN (ITEMS ONLY)	x	x	x
FEE (* ITEMS ONLY)	x	x	x
PI SUPPORT	x	x	x
NASA INTERNAL MGT SYSTEM (IMS)	x	x	x
LEVEL 3 - COL HARDWARE			
EI-1	x	x	
EI-2	x	x	
EI-n	x	x	
Structure/Mechanical	x	x	
Electrical Power	x	x	
Data Handling	x	x	
Cabling	x	x	
SYSTEMS TEST			
Operations	x		
Refurbishment	x		
Special Test Equipment	x		
SYSTEMS ENGR'G & INTEGRATION	x		
GSE	x		
MGMT & ADMIN	x	x	
FEE	x	x	

Table 6-4. COL Cost Estimating Techniques

Percent of Items	Costing Methods
33	Based on SSPDA Developed CERs
25	Based on Unofficial NASA Skylab Costs
19	Based on Vendor Catalog or Telecon Quotes
10	Based on Engineering Estimates
6	Based on Unofficial NASA Cost Data for Programs Other Than Skylab
7	Based on Design Manload and Parametric Analysis

Other costing methodology involved obtaining vendor catalog costs and vendor telecon quotes for commercial modified equipment. The remaining EI costs (23 percent) were based on engineering estimates, NASA cost data other than Skylab, and design manloading and parametric analysis.

6.3.2.2 Cost Analysis Flow Chart. Figure 6-4 shows the cost analysis flow chart, which traces the cost buildup through WBS Levels 2 and 3. Application of the cost factors and their rationale are discussed in the following paragraphs.

Test Operations. The COL system test operations cost is estimated at 6 percent of the COL total nonrecurring cost (including estimated GFE development costs). This includes all test hardware, test operations, and test support at the system level but excludes development or qualification tests of individual EIs and test facilities. The study results from the RAM study (Reference 8) was 6.8 percent and the Large Space Telescope Phase A study was 6.5 percent (Reference 9). From these results, a slightly lower factor of 6 percent was selected for a low-cost COL approach.

Special Test Equipment and Test Equipment Refurbishment. Special test equipment (5 percent) and refurbishment (10 percent) percentages were selected based on engineering estimates because no directly applicable historical data existed. Refurbishment is required to permit the use of the equipment in the Integrated Spacelab Test (WBS Level 2). For this test, 3 percent of the nonrecurring cost was selected as an allowance.

Management and Administration. Project management and administration includes all tasks associated with planning, organizing, directing, and controlling the development, production, and operations of the COL. A 5 percent allowance is used for this cost element and is typical of many NASA programs. (In the Centaur NAS3-3232 contract, program management was 5.37 percent.)

E.I. C199

INFRARED GAS ANALYZER

Contact: Lou Shaver, Infrared Industries, Inc., Santa Barbara, CA 805/684-4181

Development Cost

Total Unit Weight = 25#
65% of Weight = 16.3#
SSPDA CER 42d Mechanical/Mechanism - Low Complexity

$C_D = K_D \times 19.68 \times W^{.5}$

$C_D = (.232)\ (19.68)\ (16.3)^{.5} = \$18.4K.$

35% of Weight is Electrical - Nom Complexity = 8.7#
SSPDA CER 21m
$C_D = K_D \times 51.8\ W^{.5}$
$C_D = (1)\ (51.8)\ (8.7)^{.5} = \$153K$

$\therefore$ Total Development = \$171.2K × 1.06 (1974 \$) = \$181.5K

Commercial equipment is available and developed. Vendor contacts and engineering analysis indicates ~ 1/3 of new development cost required for space rating.

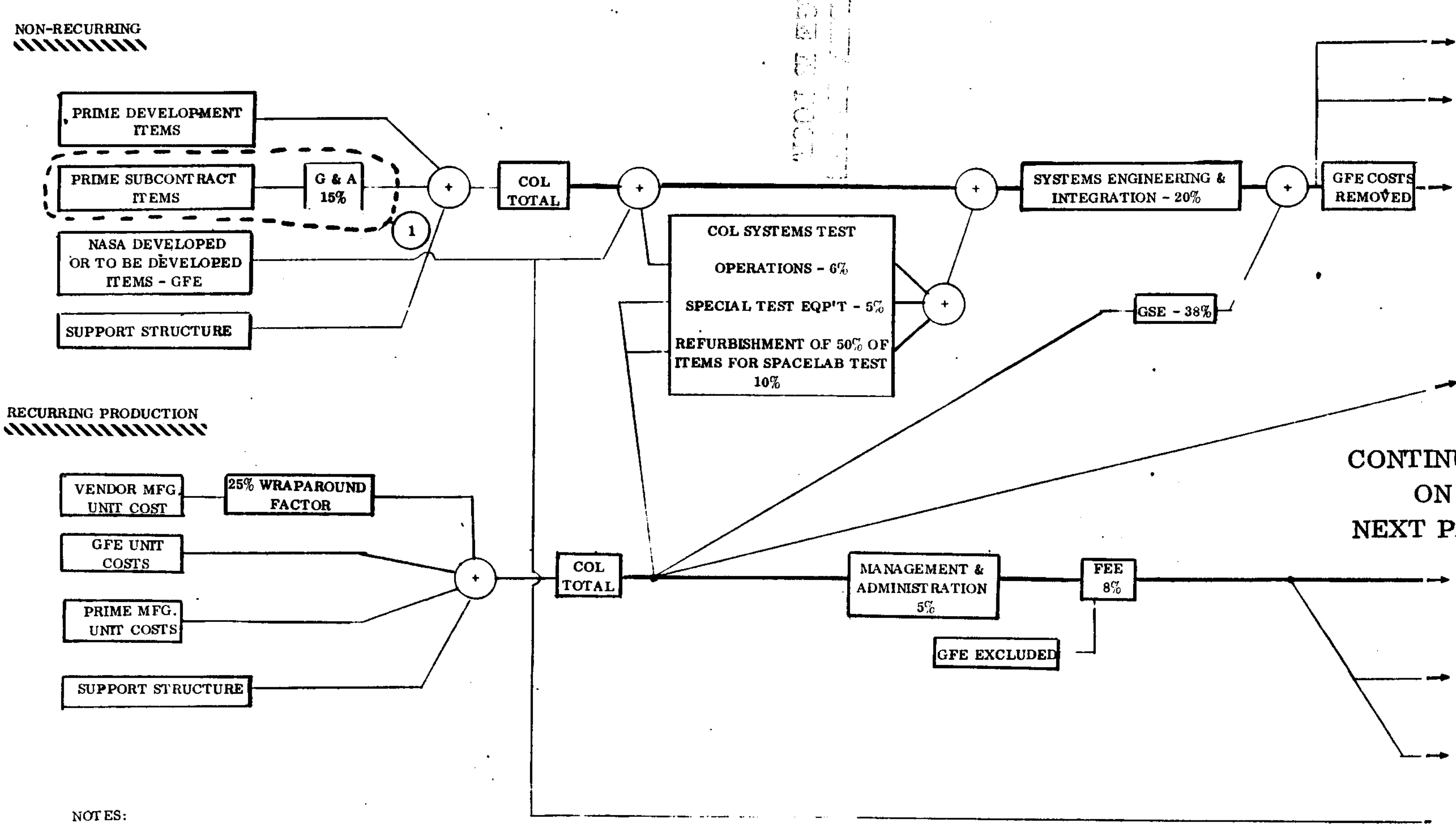
$\therefore C_D = \$61K.$

Unit Cost

Commercial unit cost - IR Industries Series 700 ~ \$2K.
Eng. ROM & Vendor Contact C_u = \$10K (5× commercial).

Confidence Level - Medium High

Figure 6-3. Example Cost Data Backup Sheet



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NOTES:

1 ALL ITEMS ARE INCLUDED UNDER PRIME DEVELOPED CATEGORY AT THIS TIME, DUE TO LACK OF IDENTIFICATION OF PRIME SUBCONTRACT ITEMS.

Figure 6-4. Life Sciences Spacelab COL Cost Analysis Flow Chart

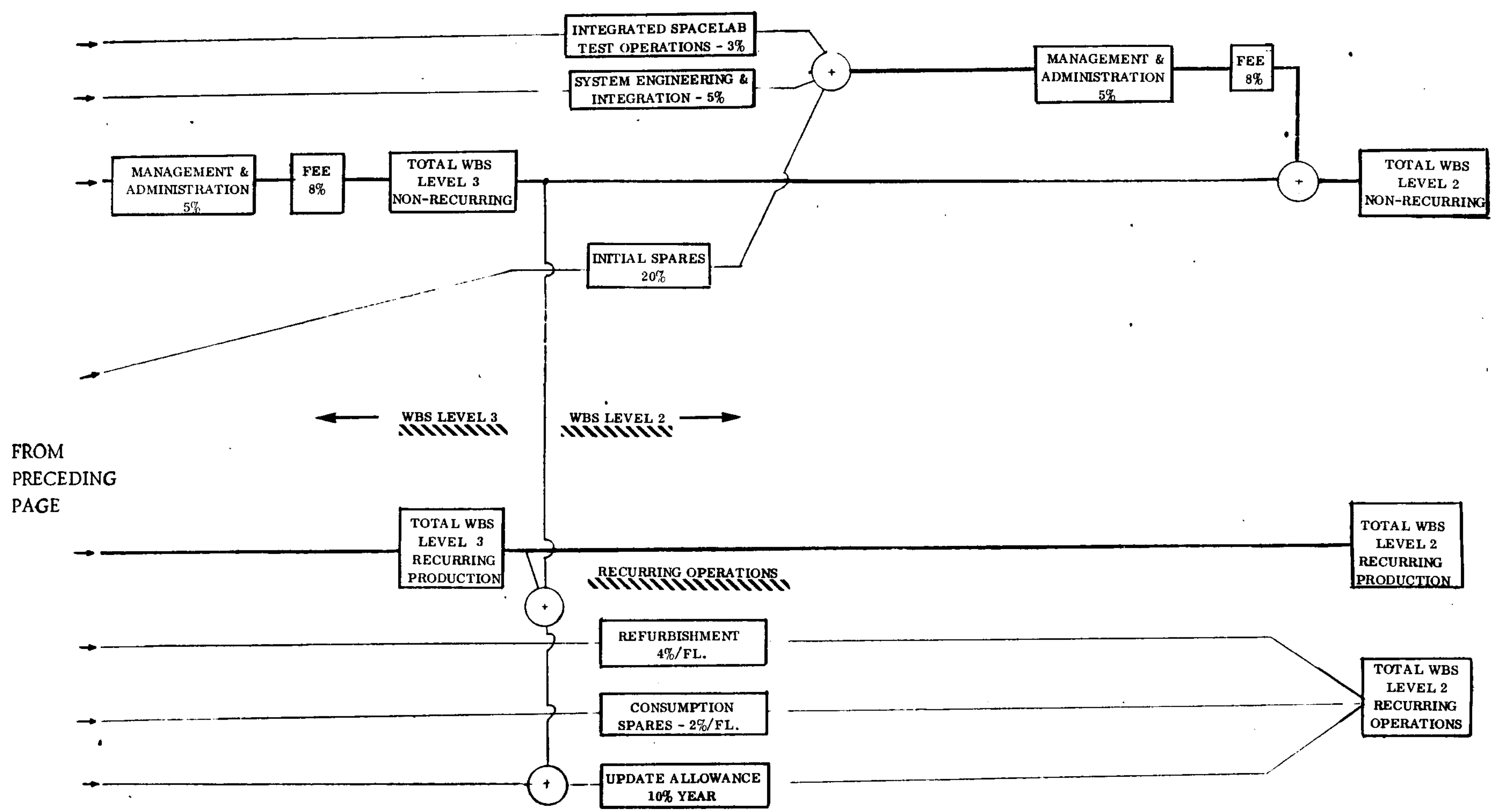


Figure 6-4. Life Sciences Spacelab COL Cost Analysis Flow Chart, Contd

System Engineering and Integration. System engineering and integration includes system analysis performance and operational requirements, interface requirements, design and control, system effectiveness analysis (reliability, QA, maintainability, human factors, safety, value engineering, etc.), integration requirements, test and checkout philosophies, specification maintenance, design reviews, technical performance measurements, and special studies. A total of 20 percent of nonrecurring was used for WBS Level 3. In addition, 5 percent was used for COL-to-Spacelab integration at WBS Level 2 to reflect payload integration tasks. The 20 percent factor is based on historical data including Centaur (21 percent). For the WBS Level 2 payload integration factor, little or no directly applicable historical data exists, and 5 percent was used until definitive studies can provide a more appropriate value.

Ground Support Equipment. The GSE cost element includes all engineering design and development, test and evaluation, and manufacture of all equipment required to support the COL. This category includes handling and transport, servicing, maintenance, and auxiliary equipment. Little or no historical data applicable to payload equipment of the type under consideration is available. Accordingly, the results of the SSPDA studies, which selected an austere allowance of 38 percent of recurring production costs, were used.

Spares. Initial spares cost based on 20 percent of recurring production and consumption spares are calculated at 2 percent recurring production cost per flight. Little or no historical data is available for specific Shuttle/Spacelab payload applications. Studies have shown a spares requirements of from less than 1 percent to numbers approaching 10 percent per flight for the Apollo program. SSPDA cost analysis used a 5 percent consumption spares allowance with no allocation for initial spares. Accordingly, the values have been selected as an allowance pending a detailed spares study.

Refurbishment. Equipment refurbishment includes all labor and support for post-flight cleanup, maintenance, and refurbishment. This includes teardown and equipment removal, scheduled maintenance, failure diagnosis and repair, equipment storage, equipment replacement and reassembly, and functional checkout and calibration. The costs were calculated as 4 percent of recurring production per flight. This included 2 percent for refurbishment and 2 percent for functional checkout and calibration. There is no directly applicable historical precedent for the type of mission operations envisioned in the Shuttle/Spacelab era. Accordingly, the values used are based on study results derived from manloading of similar type study vehicle.

Update Allowance. An update allowance of 10 percent of recurring production plus nonrecurring development cost was used for each year of the flight program. This cost element includes all sustaining engineering effort to perform modification and procurement of existing equipment plus development and acquisition of new and undefined equipment.

6.3.3 WORK BREAKDOWN STRUCTURE COST SUMMARY. Cost details for all seven COL Category A, B, and C concepts are summarized in Table 6-5 through 6-18 at the end of this section. Recurring operations costs are shown on a per-year and per-flight basis. These operating costs can be used to determine total program costs as specific COL missions are defined. Figure 6-5 summarized the total cost for the Category A biomedicine/biology COL mission based on a 24-flight, 12-year program.

6.3.4 ANNUAL FUNDING REQUIREMENTS. Funding spreads were generated only for the Category A biomedicine/biology COL and are shown in Figure 6-1 in conjunction with the schedule. Idealized cost distribution curves, as defined in NASA Data Requirements MF003M18, March 18, 1973, were used. The cost distribution curve selected for nonrecurring and recurring production phases is based on 60 percent of the funds expended at 50 percent of the program time. This distribution has historically been found reasonable because it reflects the manpower buildup early in the program, with a tailoff toward the end.

The common holding unit and cages were considered as SRT development items, and were funded separately because of their earlier start. They were then combined with the other development items to obtain the total nonrecurring funding spread.

Figure 6-1 shows $48K in nonrecurring costs during fiscal year 1980. This represents a portion of the initial spares cost scheduled during the procurement phase. Recurring operations funding spread is based on the number of scheduled flights per year and a constant update allowance per year.

Figure 6-6 shows the cost distribution curves for cumulative funding requirements.

6.3.5 COST REDUCTION GUIDELINES. Several cost reduction areas should be emphasized in addition to making maximum use of commercial equipment technology. First and most important is the use of cost performance trade studies, together with a design-to-cost approach. Historically, the performance requirements for a design have been established with minimum if any consideration for their effect on cost. Consequently, large cost penalties are incurred for small or unnecessary increases in performance. In the design-to-cost approach, a balance between performance and cost is accomplished. To achieve a low-cost program, the marginal cost increase to achieve a given change in performance must be known. Figure 6-7 shows a general cost/performance relationship with thresholds and goals established. These thresholds and goals must be set by the cognizant engineers and scientists so that different configurations can be analyzed to determine a cost/performance relationship.

To control total program costs, the design-to-cost approach should be used during development and production programs in conjunction with a broad range of technical tradeoff options built in to control costs. These cost-control approaches should include limitations on cost escalation, with specific items or systems subject to removal from

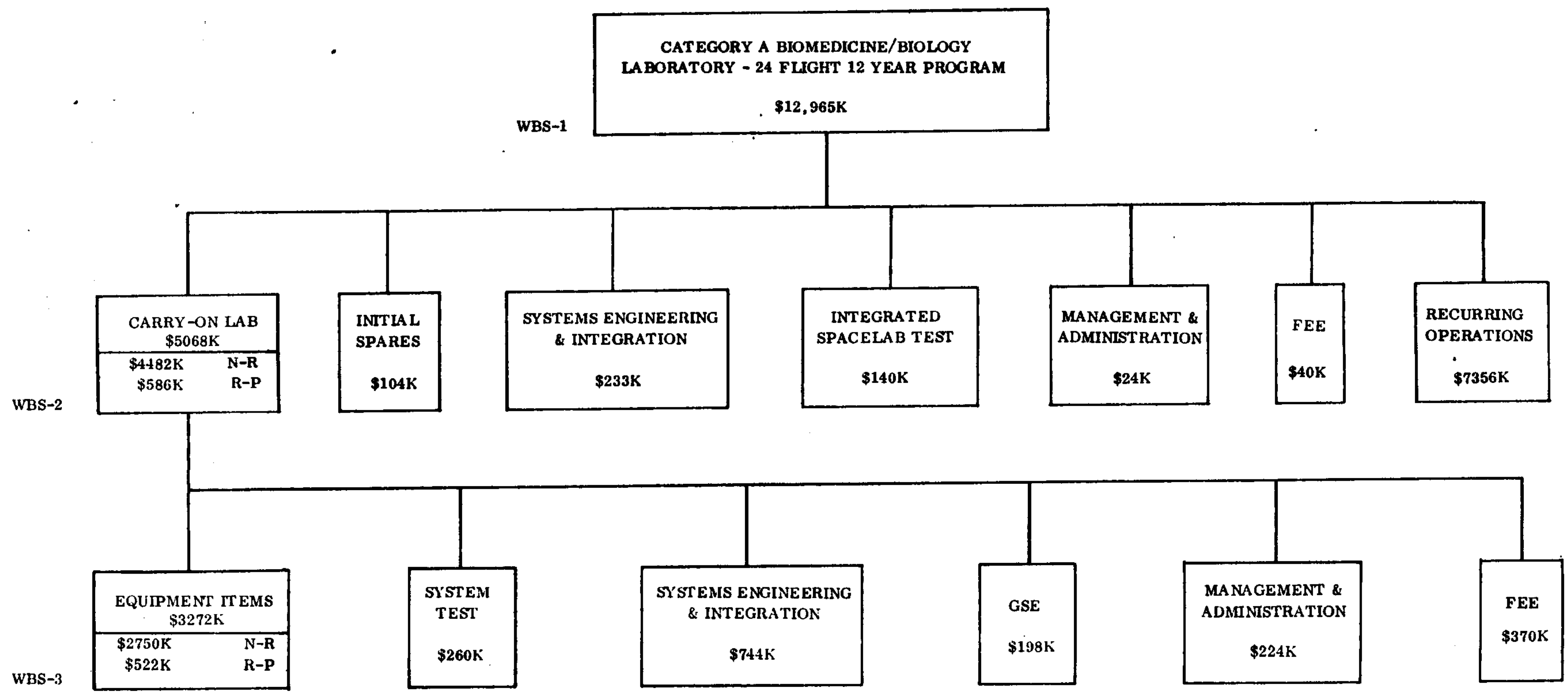
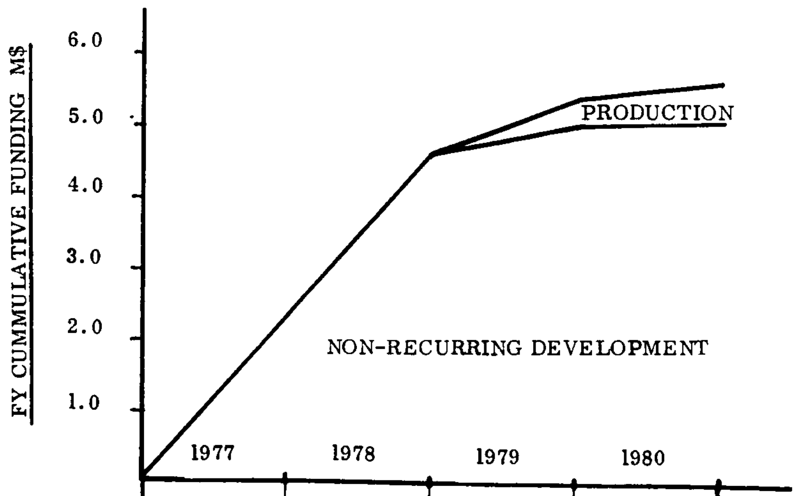


Figure 6-5. Category A Biomedicine/Biology COL Cost Summary



	1977	1978	1979	1980
DEV $K	2325	4633	4975	5023
PROD $K	0	0	352	586
TOTAL $K	2325	4633	5327	5609

Figure 6-6. Cumulative Funding

the program if the price rises beyond set limits. This approach has been successful in military programs and is being incorporated into the European Spacelab development program.

One area that resulted in high costs on past programs is frequent design criteria iterations. This causes redesign and retesting in many cases, with consequent schedule and cost impacts. Design criteria, once established, should not be changed, even if some performance degradation will result. Similarly, if interface parameters are not firm until late in a program, there will be a similar effect and large cost increases will result. These criteria, therefore, should be firmly established early in a program and limited as to change.

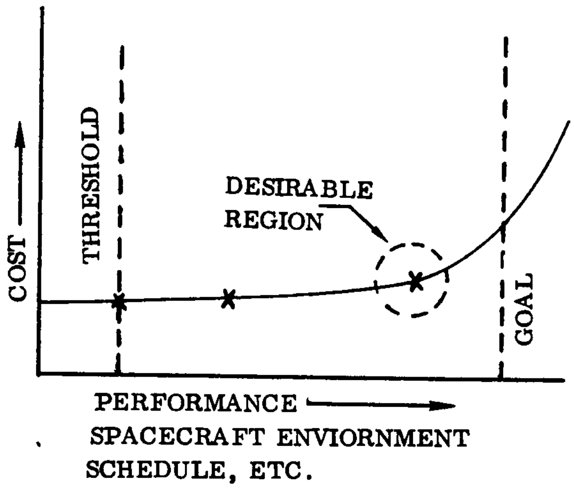


Figure 6-7. Cost Performance Relationship

Significant cost reductions can be achieved in the area of reliability by relaxing requirements in areas where crew safety is not involved. Payload reliability requirements can be further reduced because of the many flight opportunities in the mission and the capability to perform onboard maintenance. Use of off-the-shelf and custom commercial equipment with inherent high reliability will also tend to reduce costs associated with reliability.

Commonality of equipment associated with the various scientific disciplines scheduled for the Shuttle/Spacelab operation provides an opportunity for cost savings. Equipment such as cameras and recorders are likely candidates for this cost reduction.

Table 6-5. Biomedicine/Biology COL (Category A) *, WBS Level 3 (K $)

	C_D	C_u
AIR PARTICLE SAMPLER	11	1
AUTO. POTEN. ELECTROLYTE ANALYZER	(400)	70 GFE
BLOOD SAMPLE PROCESSOR CENTRIFUGE	10	10
CAGE, SMALL VERTEBRATES (8)	224	28
COMMON HOLDING UNIT	1544	55
CAMERA, VIDEO, COLOR	** (300)	100
CAMERA, 35MM	0	1
COUPLERS (12)	30	14
CREW MOBILITY AIDS	2	1
CREW RESTRAINTS	3	1.8
DISPLAYS, NUMERIC	6.5	1
DRY STORAGE CONTAINER (ROOM TEMP.)	5	.2
EQUIPMENT RESTRAINTS	4.6	2
FREEZER, GENERAL	54	5
FREEZER, LOW TEMPERATURE	81	6
INCUBATOR, 37C (MINI)	20	1
KIT, ANIMAL PHYSIOLOGY	19	2
KIT, CLEAN-UP	40	4
KIT, GENERAL TOOL	16	1.4
KIT, HEMATOLOGY	74	6
KIT, HISTOLOGY	8	.7
KIT, HUMAN PHYSIOLOGY	16	1.6
KIT, MICROBIOLOTY	17.7	1.5
KIT, MICRODISSECTION	13	1
KIT, VERTEBRATE MANAGEMENT	13	1.1
LAMP, PORTABLE PHOTO	** (10)	3
LOG BOOKS	.5	<.1
MASS SPECTROMETER	100	100
MICROSCOPE, COMPD W/PHOTO ADAPT	2	3.5
MICROSCOPE, DISSECTING	1	2
OSCILLOSCOPE	8	2.5
RADIOISOTOPE TRACER	2.4	.5
RECORDER, VOICE	2	.3
REFRIGERATOR	59	4
SENSORS, MISCELLANEOUS	8	10
SHROUD, DEBRIS CONTAINMENT	15	.5
STERILIZER, TOOL (BACTECINERATOR)	5	.5
TEMPERATURE PROBES (6)	0	.3
TIMER, EVENT	0	.2
VACUUM CLEANER	38	5.7
VENTILATION UNIT, SMALL VERT.	59	21
WASTE STORAGE CONTAINER	13	.5
WATER TANK, ORGANISM	56	6.5
WIRE AND CABLE	2	.2
WORK SURFACE, AIRFLOW	16	1
RESEARCH EQUIPMENT MODULE	152	35
TOTAL	2750	522
SYSTEMS TEST	260	
SYSTEMS ENG. & INTEGRATION	744	
GSE	198	
TOTAL	3952	522
MANAGEMENT & ADMINISTRATION	198	26
FEE	332	38
TOTAL	4482	586

*THIS IS THE MOST COMPREHENSIVE BIOSCIENCE COL, AND HAS THE CAPABILITY TO DO BOTH BIOMEDICAL EXPERIMENTS AND EXPERIMENTS ON SMALL VERTEBRATES. IT WEIGHS 261 KG (575 LB) AND IS DESCRIBED IN SECTION 4.2.4.1.

**DOES NOT REPRESENT ACTUALS, BUT ONLY AMOUNT USED FOR FACTOR CALCULATION BASE.

Table 6-6. Biomedicine/Biology COL (Category A), WBS Level 2 (K $)

	NON-REC	REC-PROD	REC-OPERATIONS
Carry-On Lab WBS Level 3	4482	586	
*Spares Initial	104		
*Systems Eng. & Integration	233		
*Integrated Spacelab Test	140		
Refurbishment			23/Flight
Spares - Consumption			12/Flight
Update Allowance			578 /Year
Management & Administration	24		
Fee	40		
TOTAL	$5023K	$586K	$613K/Year

*Management & Administration and Fee calculated on these items only.

Table 6-7. MSI COL*, WBS Level 3 (K $)

		NON-REC	REC-PROD
Camera, Video, Color		(300) **	100 GFE
Camera, 35 mm		0	1
Camera, Mounts		6	.5
Camera Timer, Video		10	.3
Crew Mobility Aids		2	.1
Crew Restraints		3	1.8
Equipment Restraints		4.6	.2
Kit, General Tool		16	1.4
Lamp, Portable Photo		(10)	3
Log Book		.5	.1
Microphone		1	.2
Timer, Event		0	.2 GFE
Video, Tape		0	.1
Video, Tape Recorder		15	2
Research Equipment Module		58	13.3
Experiment Specific Module		10.9	4.6
	TOTAL	127	129.7
Systems Test		39	
Systems Eng. & Int.		95	
GSE		49	
	TOTAL	310	129.7
Management & Admin.		15	6.5
Fee		26	2.9
	TOTAL	351	139

*The primary capability of this MSI COL is audio-visual measurements. The COL weighs 88 kg (193 lb) and is described in Section 4.3

**Does not represent actuals, but used in factor calculation base.

Table 6-8. MSI COL, WBS Level 2 (K $)

		NON-REC	REC-PROD	REC-OPER
Carry-On Lab WBS Level 3		351	139	
*Spares				
Initial		26		
*Systems Eng. & Integration		31		
*Integrated Spacelab Test		19		
Refurbishment				5.5 /Flight
Spares - Consumption				2.6/Flight
Update Allowance				49 /Year
Management & Admin.		4		
Fee		6		
	TOTAL	$437K	$139K	

*Management and Administration and Fee calculated on these items only.

Table 6-9. Life Support Protective Systems COL*
(Category A), WBS Level 3 (K $)

	NON-REC	REC-PROD
CAMERA, CINE	10	6
CAMERA, VIDEO, BLACK/WHITE	1	13
CAMERA, 35 MM	0	1
CREW MOBILITY AIDS	2	1
CREW RESTRAINTS	3	1.8
DISPLAYS, NUMERIC	6.5	1
EQUIPMENT RESTRAINTS	4.6	.2
FILM, CINE	0	.2
FILM CABINET	2	1
FLOWMETERS (4)	39	3.2
GAS CHROMATOGRAPH	221	66
GAS SUPPLY VESSELS	2	6.4
INFRARED GAS ANALYZER	61	9
KIT, CHEMICAL SAMPLING	5	.5
KIT, CLEAN-UP	40	4
KIT, GENERAL TOOL	16	1.4
LAMP, PORTABLE PHOTO	(10)	3
LIQUID TANKS	56	6.5
LOG BOOKS	.5	.1
MASS MEASUREMENT DEVICE	(225)	5 GFE
MASS SPECTROMETER	100	100
PLUMBING	45	2
RECORDER, STRIP CHART	15	5
RECORDER, VOICE	2	.3
REFRIGERATOR	59	4
SENSORS, MISCELLANEOUS (8)	2	10
SHROUD, ENVIRONMENTAL	15	.5
TEMPERATURE PROBES (6)	0	.3
TIMER, EVENT	0	.2
WASTE STORAGE CONTAINER	13	.5
VACUUM CLEANER	38	5.7
VACUUM MANIFOLD	32	5
VOLT-OHMMETER (VOM)	3	1
RESEARCH EQUIPMENT MODULE	104	21.2
TOTAL	898	286
SYSTEMS TEST	96	
SYSTEMS ENG. & INTEGRATION	246	
GSE	109	—
TOTAL	1349	286
MANAGEMENT & ADMINISTRATION	67	14.3
FEE	113	23.6
TOTAL	1529	324

*THIS LSPS COL CONCEPT WILL SUPPORT VARIOUS TESTS ON LIQUID AND GAS GAS PROCESSING EQUIPMENT AS WELL AS CREW INTERFACING EQUIPMENT. IT WEIGHS 198 KG (437 LB), AND IS DESCRIBED IN SECTION 4.4.

Table 6-10. Life Support Protective Systems COL (Category A), WBS Level 2 (K $)

	NON-REC	REC-PROD	REC-OPERATIONS
Carry-on Lab WBS Level 3	1529	324	
*Spares			
Initial	57		
*Systems Eng. & Integration	79		
*Integrated Spacelab Test	48		
Refurbishment			13/Flight
Spares - Consumption			6/Flight
Update Allowance			185 /Year
Management & Administration	9		
Fee	15		
TOTAL	$1737K	$324K	

*Management & Administration and Fee calculated on these items only.

Table 6-11. Biomedicine COL (Category B)*; WBS Level 3 (K $)

	NON-REC	REC-PROD
BLOOD GAS ANALYZER	240	64
BLOOD SAMPLE PROCESSOR CENTRIFUGE	10	10
CAMERA, 35 MM	0	1
COUPLERS	30	2
CREW RESTRAINTS	3	1.8
DISPLAY , NUMERIC	6.5	1
EQUIPMENT RESTRAINTS	4.6	.2
FREEZER, GENERAL	54	5
FREEZER, LOW TEMPERATURE	81	6
KIT, HEMATOLOGY	74	6
KIT, HUMAN PHYSIOLOGY	8	.7
LOG BOOKS	.5	.1
OSCILLOSCOPE	8	2.5
RADIOISOTOPE TRACERS	2.4	.5
RECORDER, VOICE	2	.3
REFRIGERATOR	59	4
TIMER, EVENT	0	.2
WASTE STORAGE CONTAINER	13	.5
WIRE AND CABLE	2	.1
WORK SURFACE, AIRFLOW	16	1
RESEARCH EQUIPMENT MODULE	54	15
TOTAL	668	122
SYSTEMS TEST	52	
SYSTEMS ENG. & INTEGRATION	144	
GSE	46	
TOTAL	910	122
MANAGEMENT & ADMINISTRATION	46	6
FEE	76	10
TOTAL	1032	138

*THIS COL SUPPORTS BIOMEDICAL RESEARCH WITH EMPHASIS ON VESTIBULAR, BODY FLUID, ELECTROLYTE, AND CARDIOVASCULAR FUNCTIONS. THE COL WEIGHS 85 KG (187 LB), AND IS DESCRIBED IN SECTION 4.2.3.

Table 6-12. Biomedicine (Category B) COL WBS Level 2 (K $)

	NON-REC	REC-PROD	REC-OPERATIONS
Carry-On Lab WBS Level 3	1032	138	
*Spares - Initial	24		
*Systems Eng. & Integration	46		
*Integrated Spacelab Test	27		
Refurbishment			5.5/Flight
Spares - Consumption			2.7/Flight
Update Allowance			117/Year
Management & Administration	5		
Fee	8	—	
TOTAL	1142	138	

Table 6-13. Concept C_1 COL*, WBS Level 3 (K $)

		NON-REC	REC-PROD
Automatic Potentiometric Electrolyte Analyzer		(400)**	70 GFE
Blood Acquisition Kit		4	.7
Urine Acquisition Kit		2.5	.1
Physical Examination Kit		3	3.6
Equipment Restraints		4.6	.2
Waste Storage Bag		.5	.1
Log Book		.5	.1
Oculogyral Illusion Box		.5	.1
Voice Recorder		2	.5
Structure		9.7	3.3
	TOTAL	27.3	78.7
Systems Test		21.5	-
Systems Eng. & Integration		49.7	
GSE		29.9	
	TOTAL	128.4	78.7
Management & Administration		6.4	3.9
Fee		10.8	1.0
	TOTAL	146	84

*This is one of the small biomedical Category C COLs which are limited to 23 kg (50 lb). It emphasizes real-time electrolyte studies and vestibular function studies. It is described in Section 4.2.2.1.

**Used $200K for factor calculation base due to minimal integration and test interaction with other kit items.

Table 6-14. Concept C_1 COL, WBS Level 2 (K $)

	NON-REC	REC-PROD	REC-OPERATIONS
Carry-On Lab WBS Level 3	146	84	
*Spares			
Initial	15.7		
*Systems Eng. & Integration	16.4		
*Integrated Spacelab Test	9.8		
Refurbishment			3.4/Flight
Spares - Consumption			1.7/Flight
Update Allowance			42.7/Year
Management & Administration	2.1	-	
Fee	3.5	-	
	$194K	$84K	

*Management & Administration and Fee calculated on these items only.

Table 6-15. Concept C_2 COL*, WBS Level 3 (K $)

		NON-REC	REC-PROD
Blood Sample Processor, Centrifuge		10	10 GFE
Blood Acquisition Kit		4	.7
Freezer, -70°C		81	6
Structure		9.7	3.3
	TOTAL	104.7	20
Systems Test		8.3	-
Systems Eng. & Integration		22.6	-
GSE		7.6	
	TOTAL	143	20
Management & Administration		7.0	1
Fee			.9
	TOTAL	$162 K	$22K

*This is one of the small biomedical Category C COLs which are limited to 23 kg (50 lb). It emphasizes body fluid composition and electrolyte experiments. The COL is described in Section 4.2.2.2.

Table 6-16. Concept C_2 COL, WBS Level 2 (K $)

	NON-REC	REC-PROD	REC-OPERATIONS
Carry-On Lab WBS Level 3	162	22	
*Spares			
Initial	4		
*Systems Eng. & Integration	7		
*Integrated Spacelab Test	4		
Refurbishment			.9/Flight
Spares - Consumption			.4/Flight
Update Allowance			18/Year
Management & Administration	.8		
Fee	1.3	-	
TOTAL	$179 K	$22K	

*Management & Administration and Fee calculated on these items only.

Table 6-17. Category C_3 COL, WBS Level 2 (K $)

	NON-REC	REC-PROD	REC-OPERATIONS
Carry-On Lab WBS Level 3	133	23	
*Spares			
Initial	4.2		
Systems Eng. & Integration	5.9	-	
*Integrated Spacelab Test	3.5		
Refurbishment			.9/Flight
*Spares - Consumption			.4/Flight
Update Allowance			16/Year
Management & Administration	.7		
Fee	1.2		
TOTAL	$149 K	$23K	

*Management and Administration and Fee calculated on these items only.

Table 6-18. Concept C_3 COL*, WBS Level 3 (K $)

	NON-REC	REC-PROD
Freezer, -20°C	54	5
Physical Examination Kit	3	3.6
Couplers (VCG only, Skylab)	5.6	7.3
Wire & Cable	2	0.2
Oculogyral Illusion Box	0.5	0.1
Urine Acquisition Kit	2.5	0.1
Radioisotope Tracers	2.4	0.5
Blood Acquisition Kit	4.0	0.7
Log Book	0.5	0.1
Waste Storage Bags	0.5	0.1
Structure	9.7	3.3
	$84.7 K	$21 K
Systems Test	7	
Systems Eng. & Integration	18	-
GSE	8.0	
	118	21
Management & Administration	5.8	1
Fee	9.9	1.1
	$133 K	$23K

*This is one of the small biomedical Category C COLs which are limited to 23 kg (50 lb) or under. It emphasizes urine composition, cardiovascular functions and vestibular studies. It is described in Section 4.2.2.3.

SECTION 7

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